IBA

TECHNICAL REVIEW

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Independent Local Radio

IBA INDEPENDENT BROADCASTING AUTHORITY

IBA TECHNICAL REVIEW September 1974

5 Independent Local Radio

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IBA

INDEPENDENT BROADCASTING AUTHORITY

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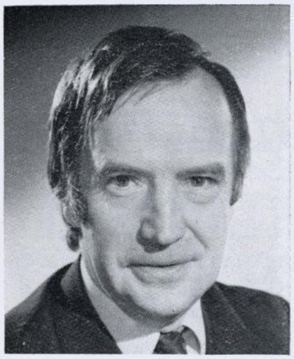
NOTE:

Code of Practice for Independent Local Radio Studio Performance

Under the terms of the Independent Broadcasting Authority Act 1973 the IBA is required to ensure that high quality technical standards are provided and maintained. The Authority's Code of Practice for Independent Local Radio Studio Performance, which is frequently referred to in the following articles, sets out the tolerances and standards to be aimed for on a day-to-day basis. The Code is reproduced in *IBA Technical Review 2: Technical Reference Book*.

At First Hearing



by John Thompson
Director of Radio
Independent Broadcasting
Authority

Ears are for listening, and ears are for hearing. In setting up the new system of Independent Local Radio the first and fundamental stage was to ensure, quite literally, that the service could be heard; and that is the connecting theme in this volume of the *IBA Technical Review*.

My colleagues in the IBA's Engineering Division have faced and met a formidable challenge. The objective data, the cool prose, and the staid statistics of the essays here reveal many aspects of the formal work achieved and the investigations made.

However, applied engineering is only partly a science. It is also an art that conceals art, and it is a highly practical affair too. Watching as a non-engineer I have learnt to admire my colleagues at their work: their bluntness and yet their diplomacy, their precision and yet their flexibility, their high technical skill and yet their low human cunning.

For many years it was said (and in some quarters even thought) that the frequency spectrum was too crowded. There was no room, it was argued, for another radio service than the state's charter corporation and the other stations which had been entrenched on our set dials for several decades.

Such thinking belongs now to the past and seems as remote as the crystal set. The White Paper on 'An Alternative Service of Radio Broadcasting' published in March 1971 set out the guidelines for the introduction of the new system of up to sixty self-financing radio companies throughout the United Kingdom. Taking the White Paper as their chart the IBA engineers, part scholars and part buccaneers as they are, have now firmly established the basic groundwork for ILR. In doing so they have worked very closely with Government (the Ministry of Posts and Telecommunications, as it then was, in particular), with the BBC, the Post Office, and many other vitally important and helpful organisations both within the United Kingdom and internationally.

Like all the positive episodes in the history of engineering the story has been a mixture of the human comedy and the march of progress. To chronicle it fully, the narrative would need, on the one hand, to range over such matters as the refinements of channel planning towards the upper end of the VHF band and the exploitation of highly directional aerial systems to enable the re-use of a medium wave frequency in many different localities. But on the other hand, the story would remember too the long cold days of site-searching in industrial suburbs and the sometimes heated exchanges across committee tables in smoke-filled Whitehall offices and the bemused expression of the newly appointed contractors faced with the stringencies of the IBA's Code of Studio Practice.

Along the way there has been the occasional ingenious compromise, a touch imperfect for the taste of engineers with highly demanding standards, but providing nevertheless a practical solution by the deadline required. The final achievement is real; a modern local radio system which results from the persistent determination of the IBA's engineers to provide an effective service for the listening public.

The arrangements for hearing the first stages of ILR are now complete. After the hearing comes the listening: for ears can be seduced into listening to a local radio station only if the broadcast output is either soothing or stimulating, amusing or above all useful. Up to a crucial point the engineers can help to sift the aural pain from the pleasure. But it is the programming, and the programming alone, which can attract and hold the audience. On a local station the

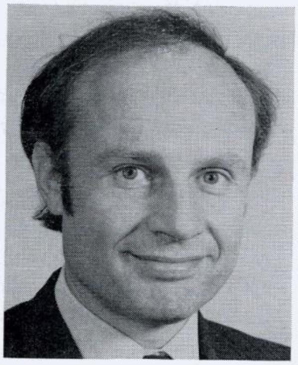
manner of the broadcasting can sometimes improve on the matter; and, equally, honest content without much style can often arrest the attention too.

Credibility and some ear appeal are the brokers between the broadcasters and the listeners. In the United Kingdom radio audiences do not move quickly, yet already the new local companies appointed by the IBA are attracting and maintaining substantial numbers. Audience loyalty is a reward that can be won only by men and women with the imagination and the tact to give their programming a popular range: easy listening but sufficiently demanding to retain and stimulate the local audience.

The initial signs are encouraging from Birmingham, Glasgow, London, Manchester and Tyne/Wear. Within about a year there should also be companies operating at Edinburgh, Liverpool, Nottingham, Plymouth, Sheffield, Swansea and Teesside; and also, following up the policy statement made on 31st July 1974 by the Home Secretary (as the Minister responsible for broadcasting affairs), the Authority plans to specify and advertise another half dozen radio contracts within a short time.

The essays in this volume describe the pioneer work achieved at this early stage by the engineers. They have built the framework which makes possible the creation of this new service of Independent Local Radio, the first of its kind in Europe.

FREDERICK WISE, BSC, graduated from the University of Southampton and then joined Vickers-Armstrong (Aircraft) Ltd to do work on UHF receiving systems and flight simulators. In 1958 he joined the IBA, and is now Head of Network and Service Planning Department. He has been a member of two CCIR study groups and his work with the IBA has included receiver design and computer techniques.



The Engineering Planning of Independent Local Radio

by F H Wise

Synopsis
The paper outlines the planning of the Independent Local Radio service from the publication of the White Paper 'An Alternative Service of Broadcasting' in 1971 to the commencement of the first programme services in 1973. It discusses some of the background to the planning work and mentions some of the special problems which arose. Of particular note were difficulties due to the operation at high power of an existing BBC VHF national service within the Local Radio sub-band, and problems due to the performance of some VHF receivers. In MF, one of the main difficulties was in connection with the siting of the London station.

It is shown that coverage of the UK by the new service will be approaching 40% by the end of 1974 or early 1975.

INTRODUCTION

The Government's White Paper 'An Alternative Service of Broadcasting' published in March 1971 explained the reasons for setting up the new Independent Local Radio service and allotted the task of administration to what was then the ITA, later to become the IBA. It was foreseen that the IBA would establish stations in up to 60 localities, each broadcasting programmes produced by local companies. The service was to be based on the use of VHF transmission and it was estimated that some 65% of the population of the UK could be covered using the frequencies available. It was recognised, however, that because of the relatively poor penetration of VHF receivers it would be imperative to provide an MF back-up service. This MF service was thought likely to be able to cover about 70% of the UK by day, but falling to 25% after dark.

The BBC were to continue to operate their 20 VHF local radio stations in England and also to provide MF back-up.

Because of the need to find a large number of new frequency allocations in the part of the VHF band available for broadcasting (up to 97·5 MHz), the White Paper envisaged that a modest reduction in BBC local radio coverage may be necessary. It was also envisaged that some of the MF allocations would come from the de-regionalisation of the BBC Radio-4 service, and restrictions of Radio-3 to a single channel. Other MF channels were to be provided through the use of non-UK assignments negotiated under Article 8 of the 1948 Copenhagen Convention and Article 9 of the Radio Regulations.

Initial Planning

The starting point for planning was a review of previous work. Earlier interest had been centred on the provision of an MF only service, and no plans had been prepared for VHF. This was hardly surprising bearing in mind that as late as the end of the 1960's only about 25% of receivers were VHF capable. Currently, most receivers sold have VHF capability, and thus the percentage able to operate on the VHF band is increasing.

It was originally intended that the first two Independent Local Radio (ILR) stations should start operating by the end of 1973, and that these would be in London.

A difficulty, however, was that plans could not be prepared for London in isolation from the rest of the UK. In order to build a station, a period of some 18 months is needed between site acquisition and station commissioning so that for commissioning in mid-1973 site acquisition was needed by the end of 1971. It became clear, therefore, that work of site finding had

to commence before the frequency planning was complete even though it was recognised that later planning developments were such as to make at least some of this work unnecessary.

In 1971 the Authority's functions did not yet include provision for local radio; the Royal Assent to the necessary legislation was not to be received until mid-1972. Special financial arrangements had to be made, therefore, for the purchase of sites, for ordering equipment and indeed for members of the Authority's staff to do the planning and site finding.

As well as the above aspects of the work, the studio side was not neglected, and a start was made by consulting with colleagues in the BBC, the radio industry and groups of potential programme company applicants leading to a Code of Practice. This code would define standards to be maintained throughout the network. On the administrative front, meanwhile, consideration was being given to the details of the amending legislation needed for the extension of the Authority's functions.

By August 1971 considerable progress had been made and a tentative VHF frequency plan had been produced, though it was based on a number of assumptions. Of particular importance was the assumption that some change could be introduced at the BBC station at Wenvoe, near Cardiff. The problem here was that an omni-directional aerial was radiating 120 kW erp at 96·5 MHz, within the local radio sub-band. This had the effect of sterilising most of the sub-band in the south and west of England and in Wales.

By this time, work was in hand in assessing the suitability of the planning standards for the needs of a commercial service, and tests were being made on domestic receiving equipment. Assessments, too, were being made of transmitting and studio equipment offered by the various manufacturers.

In the meantime, considerable effort had been expended on site finding, the majority of the work being concentrated on the key site for the London MF station. It was soon recognised that this was likely to present some difficulty and the possibility of sharing the BBC MF site at Brookmans Park was examined although, for technical reasons, this proved to be impractical.

So far, the MF planning had not proceeded to the point where the required location of the London station had been firmly established and sites were being sought in several different areas. In addition, MF site finding was continuing in the major conurbations of Birmingham and Manchester along with a few other cities. It had been decided by this time that, for the early stations, the VHF transmitters could be located at existing television or VHF radio stations.

The decision was taken by the Authority that London was to have two complementary services, one offering news and the other mainly entertainment programmes. This was one of the possibilities envisaged in the White Paper, although the implication in the White Paper was that the second service might operate in MF alone. The Authority took the view, however, that it was essential to plan for all services to operate in VHF as well as MF and that planning must proceed on that basis.

Partly because it eased the frequency planning and partly because it allowed better coverage in the target area, the two London VHF transmitters were to be sited at the IBA's London television transmitter station at Croydon.

Work in the IBA's laboratories together with the results of tests using VHF receivers by engineers at the BBC and the Ministry of Posts and Telecommunications was beginning to show that the siting of the VHF transmitters in a built-up area could, potentially, cause reception difficulties for other VHF radio broadcasting services. This is because of cross-modulation and overload effects occurring in the input stages of many Band II receivers when the input voltage of another Band II signal appearing at the input terminals exceeds about 20 mV. Discussions were held with the British Radio Equipment Manufacturers' Association (BREMA) when it was explained that the use of transmitters not co-sited with BBC VHF stations was implicit in the introduction of up to 60 independent local radio stations. Moreover, the nature of the coverage required, together with site acquisition and frequency planning constraints, sometimes made it necessary to use transmitters sited within built-up areas. It was generally agreed that it would be desirable for receivers to operate satisfactorily with unwanted Band II input signals at as high as 100 mV, as indeed some designs already allowed.

In the case of the London station at Croydon, it was proposed that the problem be overcome by using a transmitting aerial having a specially shaped vertical radiation pattern. This is provided by a 6-tier array, giving 2 kW erp towards the horizon but reducing to 100 W or so towards receiving locations within 1 mile of the transmitter, see Fig.1.

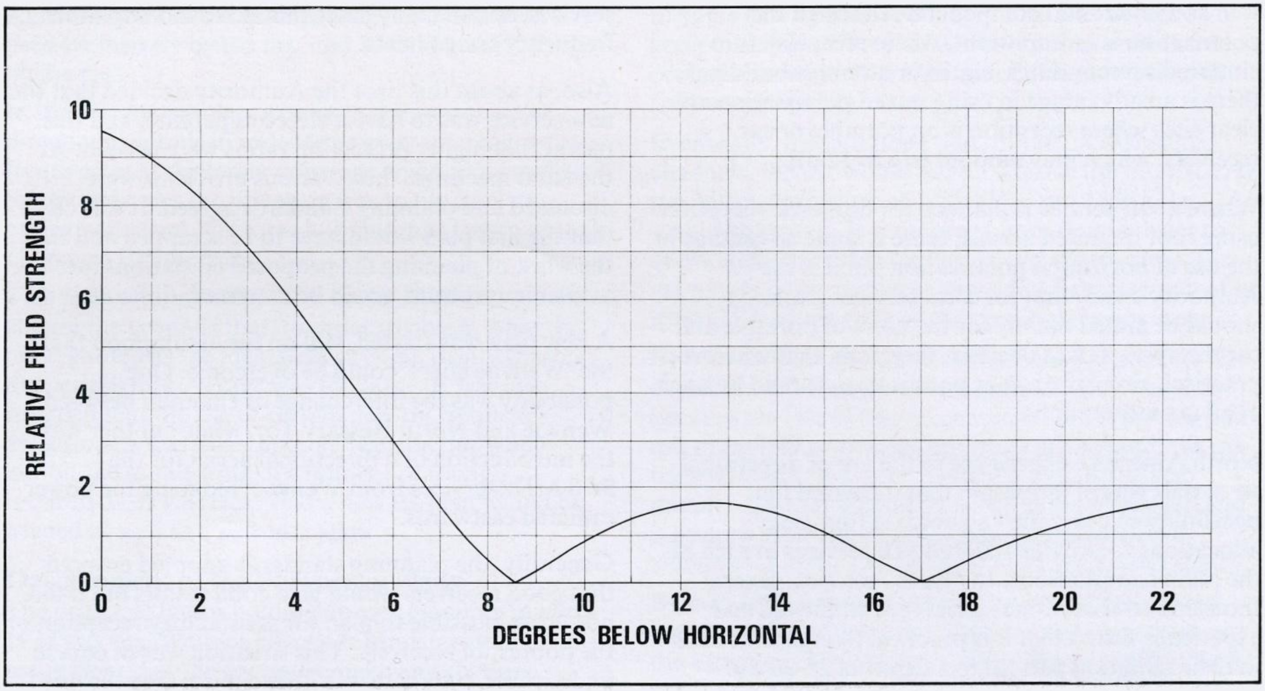


Fig.1. The nature of the coverage required by certain of the IBA's local radio services, together with the constraints imposed by site acquisition and frequency planning, makes it necessary to site transmitters within built-up areas thus incurring the risk of producing unwanted Band II receiver input signals at as high a level as 100 mV. In the case of the London station at Croydon the problem has been overcome by using a transmitting aerial with a specially shaped vertical radiation pattern shown here. This is provided by a 6-tier array, giving 2 kW erp towards the horizon but reducing to 100 W or so towards receiving locations within about 1 mile of the transmitter.

By the autumn of 1971, detailed planning was about to start. The first meeting of the Ministry's Technical Working Party (Radio) was held. This was to be the senior co-ordinating national planning committee and was attended by representatives from the IBA, the BBC, the Ministry of Posts and Telecommunications and the Post Office Corporation. The meeting was chaired by the Under Secretary responsible for broadcasting policy.

At this first TWP(R) meeting, the terms of reference of the local radio planning work was agreed. It was agreed also to set up a Local Radio Planning Group (LRPG) charged with the responsibility of agreeing frequency plans and standards. This latter was composed of members from IBA, BBC and MPT under the chairmanship of one of the Ministry's senior engineers and their first meeting was held in November 1971.

Rather than take on additional staff, it was decided by the IBA that the detailed parts of the frequency planning work should be sub-contracted to a company experienced in this type of work. A contract was awarded to Marconi Research Laboratories for this work which was to be directed by IBA staff seconded to the Ministry.

At about this time, a small team of senior IBA engineers returned from the USA and Canada where they had been investigating North American experience in the design and operation of local radio stations. The visit proved extremely valuable and a great deal of useful information was obtained.

Of special note in connection with frequency planning was the confirmation of the advantage in using mixed polarisation for VHF services and the practicability of using highly directive MF aerials.

In the VHF band, a vertical rod aerial used near the ground gives a greater signal strength when mixed polarisation is used than with horizontal polarisation. The form of the mixed polarisation appears not to be important, i.e. it may be slant or circular, the main requirement being that it should contain a vertical as

well as a horizontal component. Although the polarisation is unimportant, where reception is in cluttered surroundings, e.g. in or amongst buildings, there is an advantage in using mixed polarisation at clear sites where reception is on portable or car receivers, which may amount to 6 to 12 dB.

Where a VHF service is planned for domestic reception using roof mounted aerials, there is some advantage in the use of horizontal polarisation but it is the Authority's view that for local services planning should be aimed mainly for the users of portable and car receivers. It was decided, therefore, that wherever practical, circular or slant polarisation should be used at all IBA VHF stations.

North American experience in the use of directional MF aerials was of interest in that it created the possibility of using the valuable UK frequency allocations to provide different ILR services in each of the main conurbations. In North America, several thousand MF directional aerials are employed and experience shows that it is practical to maintain nulls in their radiation pattern to a depth of 25-30 dB.

It is also worth noting that the MF field strength employed in American cities is 50 to 100 mV/m with a minimum requirement imposed by the FCC of 25 mV/m. Generally, the effects of absorption due to tall, steel framed buildings is probably rather less in the UK than in the USA. Nevertheless, it made clear the importance of planning MF services with city centre field strength as a parameter, as well as the field strength at the nominal boundary of the service.

Detailed Planning

The first plan to be prepared was for the VHF service. It was based on the assumption that the 'Wenvoe effect' would somehow be overcome, that frequencies should, as far as possible, be chosen from the local radio sub-band (95·0 to 97·5 MHz). Also that, apart from at Wenvoe, no frequency changes should be made to BBC services.

By the time the plan was completed, it became clear that it was not satisfactory. The work of testing VHF receivers had been completed and showed that apart from the overload effects already referred to, the selectivity characteristics were not sufficiently good to allow planning in accordance with CCIR standards. Also, more data had come to hand on the location of Home Office stations using frequencies in the broadcasting band immediately adjacent to the new services, and in many cases this led to incompatible frequency assignments.

Also, at about this time the Authority decided that the new service was to have a stereo capability, and this meant that higher protection ratios were needed. At the LRPG meetings, these various problems were discussed and planning standards agreed. It was clear that the first plan would have to be scrapped and that the work of planning the proposed 60 stations into the available spectrum would be extremely difficult.

A new plan was started, still on the assumption that the 'Wenvoe effect' could be overcome. One possibility was the interchange of channels between Wenvoe and North Hessary Tor, while another was the introduction of a directional aerial for the 96·8 MHz services from Wenvoe, reducing the power radiated eastwards.

Generally, the planning standards adopted ensured that good receivers would give good results but it did not prove possible to plan for satisfactory reception on the poorest of receivers. This situation was of course undesirable, but there was little choice. One the one hand, these compromise standards could be adopted and through liaison with BREMA it could be hoped that future receivers would improve; on the other, planning could proceed on the basis of ensuring that even the poorest of receivers would operate satisfactorily. Unfortunately, this latter policy was not compatible with meeting the coverage requirements for the service as set out in the White Paper. Perhaps the ideal solution would have been to make use of some of the VHF broadcasting band above 97·5 MHz. This option was not available however, as the UK, along with France, remain the only two European countries with non-broadcast services included in Band II below 100 MHz.

Consideration by the Authority of further social and commercial factors led to the need to revise the target coverage for the next plan. One such change was that Wolverhampton and the Black Country should be split off from Birmingham and have a separate service. Also at this time, it was agreed that the BBC could increase the coverage of Radio Leeds to provide more regional coverage. Additionally, a new BBC station, Radio Carlisle, was to replace Radio Durham.

Some progress meanwhile had been made with MF planning. At the time, UK frequencies released for local radio by de-regionalisation of the Radio-4 network were 1151 kHz, 1340 kHz and 1546 kHz.

Agreement was then reached that 1151 kHz would be used exclusively by the IBA, and 1340 kHz exclusively by the BBC.

In the first IBA MF plan, extensive use was made of directional aerials in order to employ UK assigned frequencies at the larger coverage areas. For smaller towns and cities the intention was to use non-UK assignments and, for some BBC stations, International Common Frequencies.

This plan was not acceptable to the Ministry nor the BBC on the grounds that, in order to obtain what the IBA regarded as the ideal field strength in city centres, the peripheral coverage was too large. It was also revealed that the use of certain non-UK frequency assignments was unacceptable because this would inhibit the monitoring of a number of foreign broadcasts. It was clear that a new MF plan would be needed as well as a new VHF plan.

Development of the Frequency Plans

The principle factor holding up VHF planning in early 1972 was the 'Wenvoe effect'. A Ministry ruling had made clear that the BBC must make any changes necessary at Wenvoe in order to allow the introduction of ILR services. The BBC made proposals for a directional aerial to be installed at Wenvoe which reduced the erp towards England by about 14 dB.

This seemed very helpful and work was started again, making the assumption that this would be possible. However, after some months it emerged that the Wenvoe mast would not carry the load of an additional aerial and replacement of the mast would require planning consent. Thus the whole exercise would take longer than the time available if ILR was to meet the required timescale. It had to be agreed therefore, that planning was to be on the basis of the high power transmissions from Wenvoe remaining on 96·8 MHz. The only change made at Wenvoe was to interchange frequencies between the Radio-3 and Radio-4 (Wales) services so that the latter rather than the former service used 96·8 MHz. By this means, it would not be necessary to plan ILR to give protection to the BBC service on this frequency outside Wales. Once more, therefore, VHF planning had to recommence.

During this time, further difficulties had occurred in the MF planning. For various reasons, the frequencies available to local radio following the de-regionalisation of BBC Radio-4 were to be changed. By now, however, the Authority were firmly committed to the use of 1151 kHz in the large conurbations and were reluctant to agree to a frequency change. This and matters of acceptable power level of ILR MF stations continued to occupy a considerable amount of discussion time at LRPG meetings.

Eventually, it was agreed that, of the UK assigned channels, the IBA would have exclusive use of 1151 kHz, the BBC exclusive use of 1457 kHz, and 1546 kHz would be shared. It was agreed, too, that in order to allow adequate field strength in city centre areas, the IBA would be permitted to provide a field strength of up to 3 mV/m at the edge of the nominal service area.

By March 1972, there was substantial progress on the development of MF planning. A new factor was that because the Isle of Man commercial radio service was not permitted to provide coverage in England, the IBA transmissions had to be restricted in a reciprocal manner. Several stations in the area were affected and it became essential to plan them with directional aerials which otherwise would have been unnecessary.

By mid-1972 the MF plan was completed and agreed, and there was substantial progress and agreement on the VHF plan. The problem of the 'Wenvoe effect' had made planning extremely difficult and had led to a situation where frequency changes were needed at over half of the BBC local radio stations and where some reduction in effective BBC local radio coverage was necessary in one or two cases.

The VHF plan was finally completed by June 1972 and, as well as the factors already mentioned, it included an extension to the coverage of BBC Sheffield. Finally, the development allowing completion of the plan was that the Ministry had managed to negotiate some changes to the frequency of Home Office services operating immediately above 97·5 MHz.

In July 1972, both the MF and VHF plans were formally agreed by the TWP(R). Even so, several problems remained, the major one being the London MF site.

MF Transmitter for London

For the London MF station to be ready for service by autumn 1973, the site should have been acquired by spring 1972 at the latest. In spite of the considerable effort expended on site finding, however, a site had not been acquired. Altogether about 200 sites had been investigated of which about 30 were technically suitable.

For the two London MF services, the frequency assignments were 1151 kHz and 1546 kHz. These assignments were also to be used elsewhere, the former at Birmingham, Manchester, Tyneside, Glasgow and

Plymouth and the latter at Wolverhampton, Liverpool, Edinburgh, Sheffield and by the BBC at Teesside and Bristol. In order to avoid mutual interference, it was necessary for the station to be located near the edge of the required service area and in the north west quadrant. Inevitably, this put the station in the London Green Belt and led to acute difficulty in obtaining planning permission.

One site was found towards the west. It was close to a reservoir, a new motorway flyover and a rubbish destructor. Considerable hope was held that this would be acceptable to the planners but eventually the planning application was rejected on the grounds of destroying local amenities.

It became clear that if the London service was to start on schedule, some temporary arrangements would be necessary. To this end an MF station was planned for location in central London.

In order to obtain adequate coverage without use of high power, it was essential to use a low frequency, i.e. less than about 800 kHz. Allowing for the various restrictions imposed by the need to avoid interference to other services, the choice of frequency was very limited and only about three were practical. International negotiations were put in hand immediately for clearance to use two of these frequencies under Article 8 of the Copenhagen Convention and a search started for a temporary station site. The site eventually chosen was at the Lots Road power station of the London Transport Board. A 'T' aerial was planned which was to be supported between two chimneys.

The frequencies to be used were 557 kHz and 719 kHz. Three months after application for clearance, and only a few weeks before clearance was received, the unauthorised station Radio Veronica which had been broadcasting since May 1960 on 1562 kHz, changed frequency to 557 kHz.

There was little choice but to accept this situation and although it would have been possible to find an alternative frequency to 557 kHz, on balance there would be no overall improvement to the IBA service on any other frequency currently available. It was planned to continue with the original choice and test transmissions from Lots Road started early in 1973.

Meanwhile, three possible sites had been found for the permanent London station, one at Bayhurst Wood and two at Saffron Green near Barnet. Outline planning applications were submitted and each was rejected. It was evident by this time that if the stations were ever to be built, a planning appeal against these refusals would be required.

The decision to appeal was not lightly taken and it was in fact the first time in the history of the Authority that a planning appeal had been necessary. The appeals were held in November/December 1972 and permission was finally granted for one of the Saffron Green sites in April 1973. Thus, plans were put in hand to complete the Saffron Green station by about the beginning of 1975 so that the temporary station at Lots Road would be in operation for just over a year.

The First ILR Stations

Announcements were made in Parliament giving the areas where the first 27 of the proposed 60 or so ILR stations were intended to be built, though this has since been reduced to a total of 19.

As planned, the first stations came on air in London in 1973 with the news service commencing on October 8th and the general entertainment service commencing on October 16th. By Easter 1974 services were also available in Glasgow, Birmingham and Manchester. Further stations at Tyne/Wear and Swansea opened a few months later while Edinburgh, Liverpool, Plymouth and Sheffield are planned to be in service by the end of 1974 or early 1975.

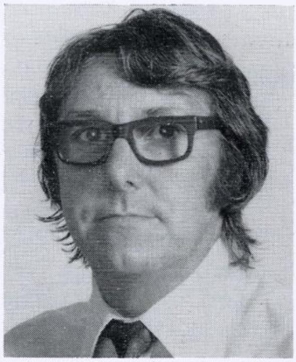
During the commissioning and initial operation of the first MF stations, it has been possible to evaluate the performance of the directional aerials. These vary in complexity at the different stations with the more highly directive arrays at Birmingham, Manchester and, later, London. Each employs four masts and requires nulls towards co-channel stations of depth up to 25 dB and the designs are such that restrictions are applied also to limit sky-wave interference to co-channel stations. Experience has shown that the theoretical design performance can be realised in practice.

Future Plans

The stations now operational in London, Birmingham, Manchester, Glasgow, Tyne/Wear and Swansea provide a United Kingdom population coverage of about 30%. When the stations in Liverpool and Sheffield come into service this figure will rise to a little below 40%.

Current plans allow some flexibility in the selection of later stations for providing a further 20%–30% coverage and these will be decided with due consideration being given to commercial and social factors.

DEREK CHAMBERS, MIEEE, joined the Independent Broadcasting Authority in 1970 from the BBC, where he had been engaged on a number of projects. Amongst these was the design and construction of UHF relay stations and VHF radio stations in the Transmitter Capital Projects Department. Prior to this, he spent several years in industry, where he worked on the research and development of a wide range of topics in the electronics field. His earlier work with the IBA was as a Senior Engineer working on UHF transmitting aerial systems, and in 1972 he became Head of the Authority's new Local Radio Project Section. He is married with two children, and lives in Surrey.



Independent Local Radio Transmitting Stations

by D S Chambers

Synopsis

This article outlines the technical system arrangements at the IBA's Independent Local Radio VHF and MF transmitting stations. The programme input equipment, transmitters and aerial systems are described, together with a brief description of the monitoring arrangements. The transmitter performance specifications are outlined, together with the radiation pattern requirements at some typical VHF and MF stations. Of particular note is the use of circular polarisation for the VHF service and directional medium wave transmitting aerials.

INTRODUCTION

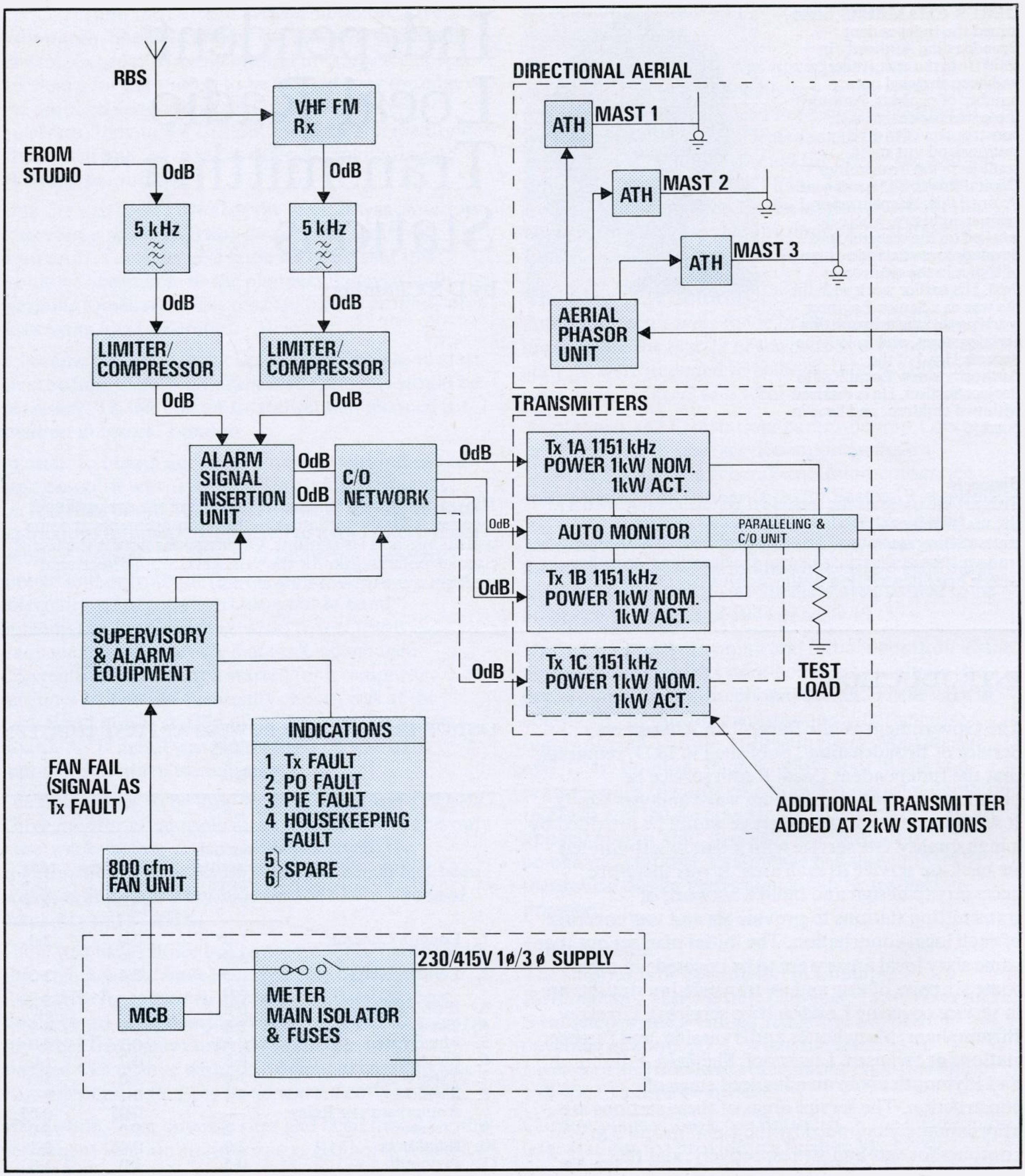
The Government White Paper, 'An Alternative Service of Broadcasting', published in 1971, required that the Independent Local Radio service be broadcast on both the medium wave and VHF bands. It was planned that the coverage would be provided by a high quality VHF service with a bandwidth-limited MF back-up service in each area. It was therefore necessary to design and build a network of transmitting stations to provide MF and VHF coverage of each local conurbation. The initial plan set out that some sixty local areas were to be covered; of these some six pairs of VHF and MF transmitting stations are in service covering London (two services), Glasgow, Birmingham, Manchester and Tyneside, and further stations at Swansea, Liverpool, Sheffield, Edinburgh and Plymouth are in an advanced stage of construction. The service areas of these stations are approximately bounded by the 1 mV/m and 3 mV/m contours for VHF and MF respectively, and the necessary erp's (effective radiated powers) and transmitter powers required for the first thirteen stations are given in Table 1.

LIST OF TRANSMITTER POWERS AT FIRST THIRTEEN STATIONS

Table 1

		MF	VHF	
		Nominal Transmitter Power (kW)	Transmitter Power (kW)	Max. ERP (kW)
1.	London General	1·0* 25·0	0·4	2·0
2.	London News	0·5* 8·0	0·4	2·0
3.	Birmingham	0·8	1·0	2·0
4.	Glasgow	2·0	1·0	4·0
5.	Manchester	0·35	0·3	2·0
6.	Swansea	0·8	0·7	1·0
7.	Tyne/Wear	1·0	1·0	5·0
8.	Sheffield	0·4	0·1	0·1
	Rotherham VHF Relay	—	0·05	0·05
9.	Liverpool	1·2	1·0	5·0
10.	Edinburgh	2·0	0·45	0·5
11.	Plymouth	0·5	1·0	1·0
12.	Teesside	0·8	1·0	2·0
13.	Nottingham	0·25	0·3	0·3

* Temporary station


RBS
VHF FM Rx
FROM STUDIO
OdB
5 kHz
LIMITER/ COMPRESSOR
ALARM SIGNAL INSERTION UNIT
C/O NETWORK
DIRECTIONAL AERIAL
ATH
MAST 1
MAST 2
MAST 3
AERIAL PHASOR UNIT
TRANSMITTERS
Tx 1A 1151 kHz POWER 1kW NOM. 1kW ACT.
AUTO MONITOR
PARALLELING & C/O UNIT
Tx 1B 1151 kHz POWER 1kW NOM. 1kW ACT.
Tx 1C 1151 kHz POWER 1kW NOM. 1kW ACT.
TEST LOAD
ADDITIONAL TRANSMITTER ADDED AT 2kW STATIONS
SUPERVISORY & ALARM EQUIPMENT
INDICATIONS
1 Tx FAULT
2 PO FAULT
3 PIE FAULT
4 HOUSEKEEPING FAULT
5 6 SPARE
FAN FAIL (SIGNAL AS Tx FAULT)
800 cfm FAN UNIT
MCB
METER MAIN ISOLATOR & FUSES
230/415V 1ø/3ø SUPPLY

As described elsewhere in this volume of the *IBA Technical Review*, the frequency allocation and service planning aspects of the ILR network were restrained by the existing services and, as a consequence, considerable use has been made of directional aerials, particularly at MF, where the UK allocated frequencies of 1151 kHz and 1546 kHz have been used repeatedly. In addition, it was decided to take advantage of radiating a signal of mixed polarisation for the VHF services. These two factors, together with the decision to provide stereo coverage on VHF, had considerable influence on the design and construction of the transmitting stations.

It was further decided that, wherever economically viable, reserve transmitting and programme input equipment would be provided. This not only maintains continuity of service in the event of breakdown, but also allows maintenance to be carried out during programme hours. This second item was of importance since it was anticipated that Programme Contractors would require a twenty-four hour operational service.

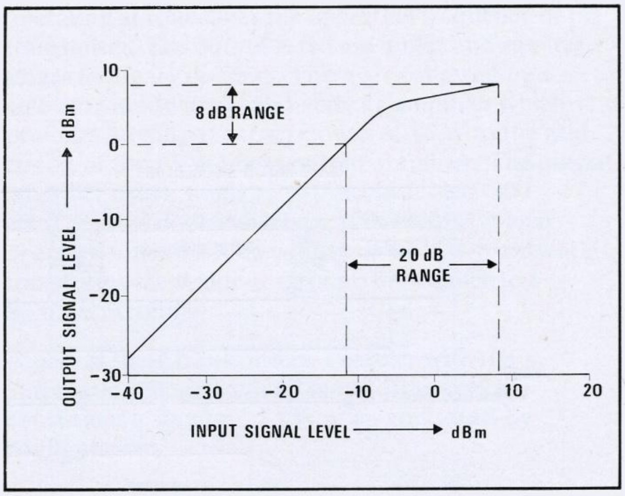


Fig.2. The MF transmitter compression characteristic. Compressors are inserted in the programme chain to provide an improvement in the signal-to-noise ratio of the MF service. A compression ratio of 12 dB is used.

In order to meet these requirements it was decided that duplicate transmitters would be provided, operating in a main/passive stand-by mode, together with duplicate programme arrangements at medium wave stations. In the case of VHF stations a pair of Post Office lines is necessary in order to provide for a stereo feed, and to meet economic restraints it was decided that the reserve condition would be obtained by reverting to the mono mode in the event of the loss of one of the programme feed chains.

All stations have been designed for automatic, unattended operation. The only remote control facilities provided are for mono/stereo switching at the VHF stations, which can be initiated from the associated studios, while monitoring of both the MF and VHF transmitting station status is signalled 'over-air' to a dedicated receiver and display located at the respective Programme Contractor's studios.

System Arrangements at Medium Wave Stations
The typical technical system arrangement at medium wave stations is shown in Fig.1.

The programme originating from the studio is fed to the transmitting station over a single PO line, consisting of a Tariff 'M' music circuit having a nominal bandwidth of 6·4 kHz, with a reserve programme feed being taken from a VHF re-broadcast link (RBL) receiver tuned to the associated VHF transmitter. The PO line and receiver feed independent programme chains, each comprising a 5 kHz low-pass filter and a compressor/limiter designed to give a 12 dB compression ratio and to limit at a level of +8 dBm, see Fig.2. Programme detectors coupled to the supervisory equipment are used to detect a line or equipment failure and these in turn are connected to a supervisory logic system which initiates the reserve condition.

Any transmitter changeover, loss of Post Office line or receiver programme feed, or a mast lighting failure (where applicable), is signalled to the studio by an 'over-air' supervisory system. This is capable of sending up to six fault conditions and operates by inserting a coded 4·7 kHz sub-carrier into the programme path in the event of a fault condition. It was decided that each of the Programme Contractors would be responsible for monitoring the ILR service

Fig.1. Block schematic of a typical system arrangement at MF stations. The main programme path from the studio is a single Post Office line which feeds the transmitters via a 5 kHz filter and compressor. The reserve programme path is provided by a receiver tuned to the associated VHF station. The transmitter configuration comprises a 1 kW main and passive stand-by arrangement, with a third transmitter added at stations needing a 2 kW output power. A typical directional aerial comprises up to four mast-radiators with the appropriate matching and phasing networks. Supervisory and monitoring equipment is provided to initiate the necessary actions in the event of failure and also to insert an alarm signal which is broadcast 'over-air' to the Programme Contractor's studio.

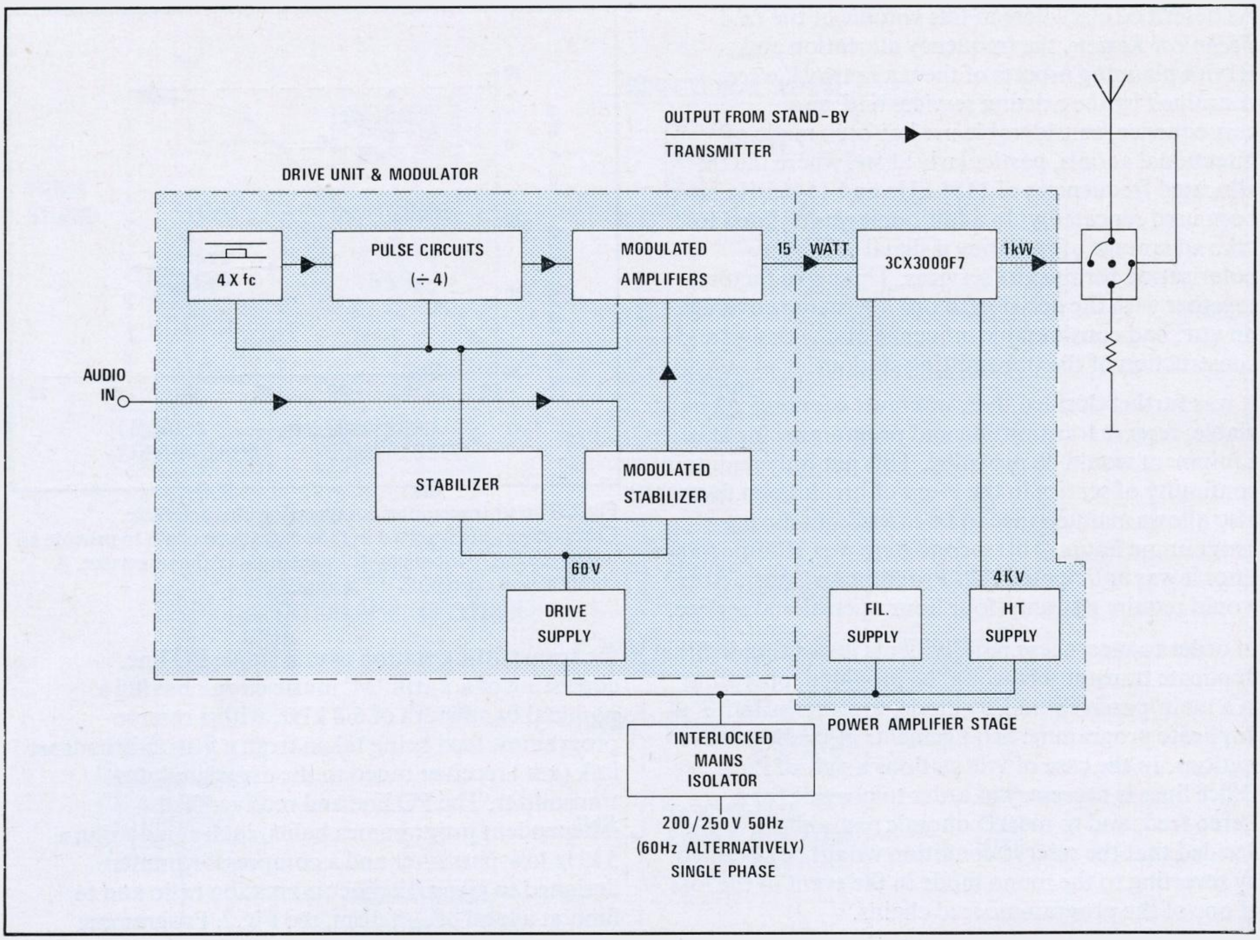


Fig.3. Block schematic of the 1kW MF transmitter which comprises an all solid-state drive unit followed by a vacuum tube triode power amplifier stage. A crystal-controlled oscillator, operating at four times the output frequency, is followed by pulse shaping circuits and binary dividers which feed a collector-modulated class C RF transistor amplifier. This provides a 15 W drive level to the 3CX3000F7 triode output amplifier stage.

appropriate to their area and consequently a dedicated receiver and decoder have been installed in the studio premises.

The 4·7 kHz sub-carrier is phase modulated to give a six bit word, +36° representing logic '1' and —36° representing logic '0'. It is appropriately coded for each fault condition. This sub-carrier is transmitted for approximately 0·5 second and its level, being approximately 30 dB below 100% modulation, is virtually imperceptible to the majority of listeners.

A more detailed description of the MF programme input equipment and the associated supervisory and monitoring arrangements is given as a separate article in this issue.

As previously mentioned, a main design requirement for the transmitter configuration was that of high reliability and ease of maintenance during programme service. In addition, it was also decided that a full-power stand-by capability was to be provided at all stations. As a consequence of this, it was apparent that a main and passive stand-by arrangement provided the most economic solution. It was clear from the service and coverage planning that the majority of MF stations would require a transmitter power of less than 1 kW, the main exception being the higher-powered London permanent MF station, and a few other sites would need to operate at 2 kW. As a result, the basic transmitters were chosen to have a power of 1 kW and to have the capability of being

under-run to 250 W. These were then specified to operate in a main and passive stand-by mode with automatic changeover.

It can be seen from Fig.1 that in the case of 2 kW stations a third transmitter is introduced. This arrangement operates with two of the 1 kW transmitters operating in parallel, while the third is in a passive stand-by mode. This third transmitter replaces either of the parallelled main transmitters in the event of failure.

The two configurations, therefore, provide a range of powers from 250 watts to 2 kW. This arrangement introduced flexibility into the early stages of the planning, when site locations and consequently radiated power and aerial gain requirements were uncertain, and also met the full-power stand-by requirement.

The transmitters themselves are manufactured by Marconi Communication Systems Ltd. and were selected from tenders offered by several manufacturers. A description of the transmitter selected for the 1 kW stations is given below.

1 kW MF Transmitter

The 1 kW MF transmitter comprises an all solid-state low-power drive unit and a single vacuum tube, a triode output amplifier. A simple block schematic of the complete transmitter is shown in Fig.3. The drive unit comprises a crystal-controlled oscillator operating at four times the operating frequency of the transmitter. The output is fed via buffer and squarer stages to binary dividers. These are followed by a collector-modulated solid-state RF amplifier which provides an output carrier power of 15 W to the grid circuit of the 1 kW linear output amplifier. The output amplifier uses a single zero-bias air-cooled (200 cu. ft./min.) triode valve type 3CX3000F7, which operates with an anode voltage of 4 kV. A π-network transforms the anode-to-ground impedance to a nominal 50 ohms.

A pair of these transmitters, together with the automatic changeover and monitoring system, constitutes a standard 1 kW main and stand-by configuration.

In the event of an amplifier, drive or modulation failure, a changeover to the stand-by transmitter is effected in less than three seconds. The use of low-level modulation and a single power-amplifier valve has enabled a simple and reliable design to be achieved and the penalty of relatively low efficiency has been accepted against these advantages (the power consumption of each transmitter is approximately 5 kW for 1 kW RF output, as against the 3 kW consumption that can be achieved with a high-level modulation system).

A summary of the MF transmitter technical specification is as follows:

Parameter	*Acceptance Limits*	*Remarks*
Audio Frequency Response	±1·5 dB over the range 30 Hz to 10 kHz	Measured at 70% modulation depth
Harmonic Distortion	⩽3% up to 75% modulation ⩽4% up to 90% modulation	
Signal/Noise Ratio (Random and Synchronous)	>54 dB unweighted with reference to 100% modulation	
Carrier Shift Level	⩽5% up to 90% modulation	
Spurious Outputs	⩾40 dB below mean carrier power and shall not exceed 50 mW	
Modulation Rating	Equipment to be capable of carrying 40% tone modulation continuously, and 100% for a minimum period of ten minutes in any one hour	
Audio Input	+8 dBm for 100% modulation	
Carrier Frequency Stability	±10 Hz over ambient temperature range 0°C to 40°C	

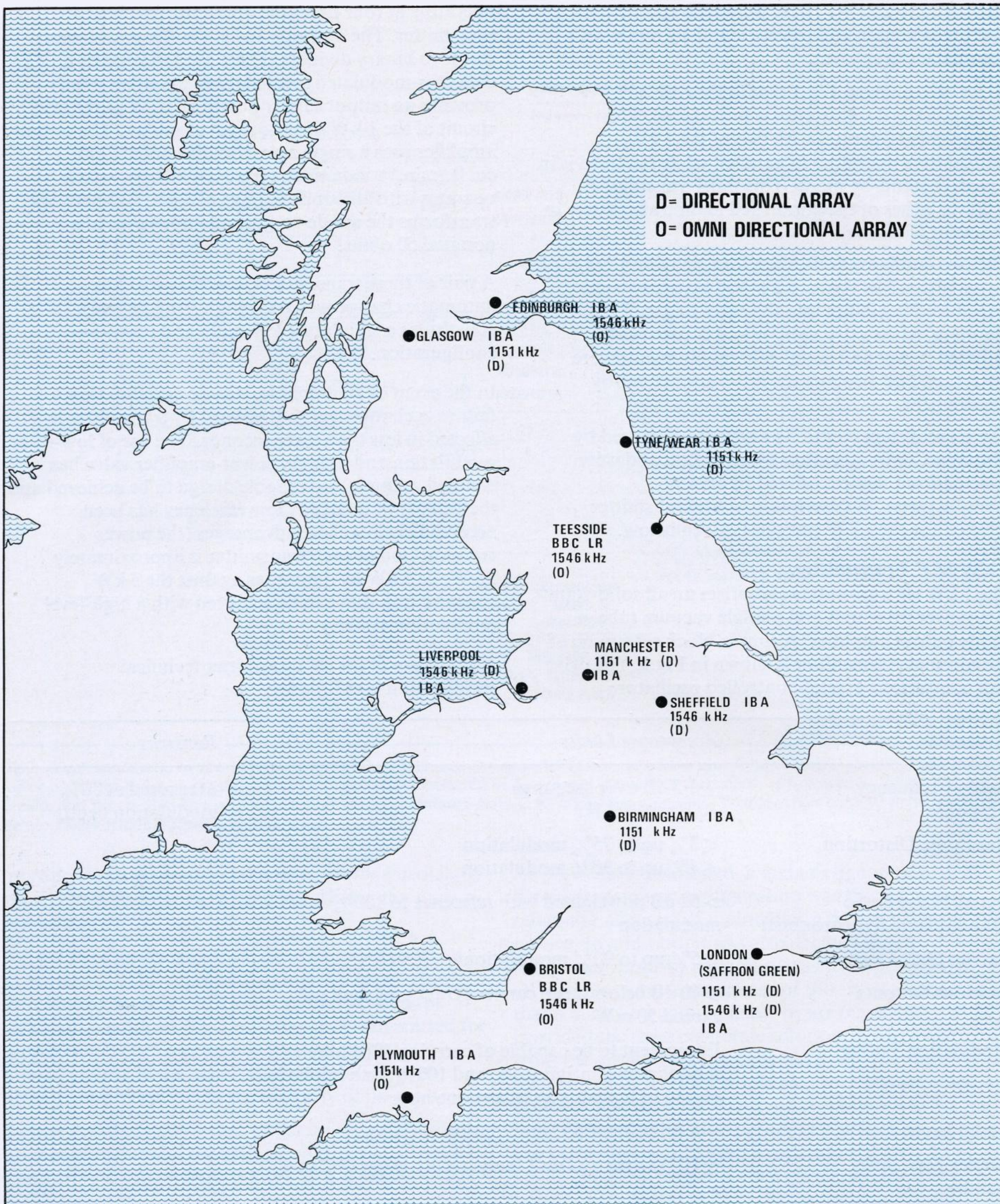

D= DIRECTIONAL ARRAY
O= OMNI DIRECTIONAL ARRAY
EDINBURGH IBA 1546 kHz (O)
GLASGOW IBA 1151 kHz (D)
TYNE/WEAR IBA 1151 kHz (D)
TEESSIDE BBC LR 1546 kHz (O)
LIVERPOOL 1546 kHz (D) IBA
MANCHESTER 1151 kHz (D) IBA
SHEFFIELD IBA 1546 kHz (D)
BIRMINGHAM IBA 1151 kHz (D)
LONDON (SAFFRON GREEN) 1151 kHz (D) 1546 kHz (D) IBA
BRISTOL BBC LR 1546 kHz (O)
PLYMOUTH IBA 1151k Hz (O)

Fig.4. Map showing location of IBA and BBC local radio stations sharing the UK assigned frequencies of 1151 kHz and 1546 kHz.

Transmitter Modulation Level

The maximum audio output from the studio is controlled to a level of +8 dBm and this has been arranged to provide a modulation depth of 90% at the transmitter. This therefore gives a 1 dB margin before the onset of clipping due to the transmitter modulator.

Directional Arrays

As explained elsewhere, one of the features of the IBA network is the use of directional medium-frequency aerials on the UK allocated frequencies of 1151 kHz, which is exclusively used by the IBA, and 1546 kHz, which is shared with the BBC. These arrays comprise up to four mast-radiators, which are approximately 90° in electrical height (65 m and 47 m for 1151 kHz and 1546 kHz respectively), and require site areas of up to 15 acres, which are covered with an extensive buried radial copper-wire earth system. The performance required from these arrays was relatively stringent, with ground-wave null requirements of up to 26 dB. In addition, skywave protection had also to be provided. The IBA stations using directional systems are shown on the map given in Fig.4, and a typical theoretical radiation pattern with the templet limits needed to protect against neighbouring co-channel stations is shown in Fig.2 of the following article on Directional MF Aerial Arrays by E T Ford.

The networks required to feed a directional array are illustrated in Fig.5, which shows in schematic form the arrangement for a four-mast array. Each radiator is impedance matched to 50 ohms, appropriate account being taken of mutual impedance and the current distribution. The necessary phase and amplitude of

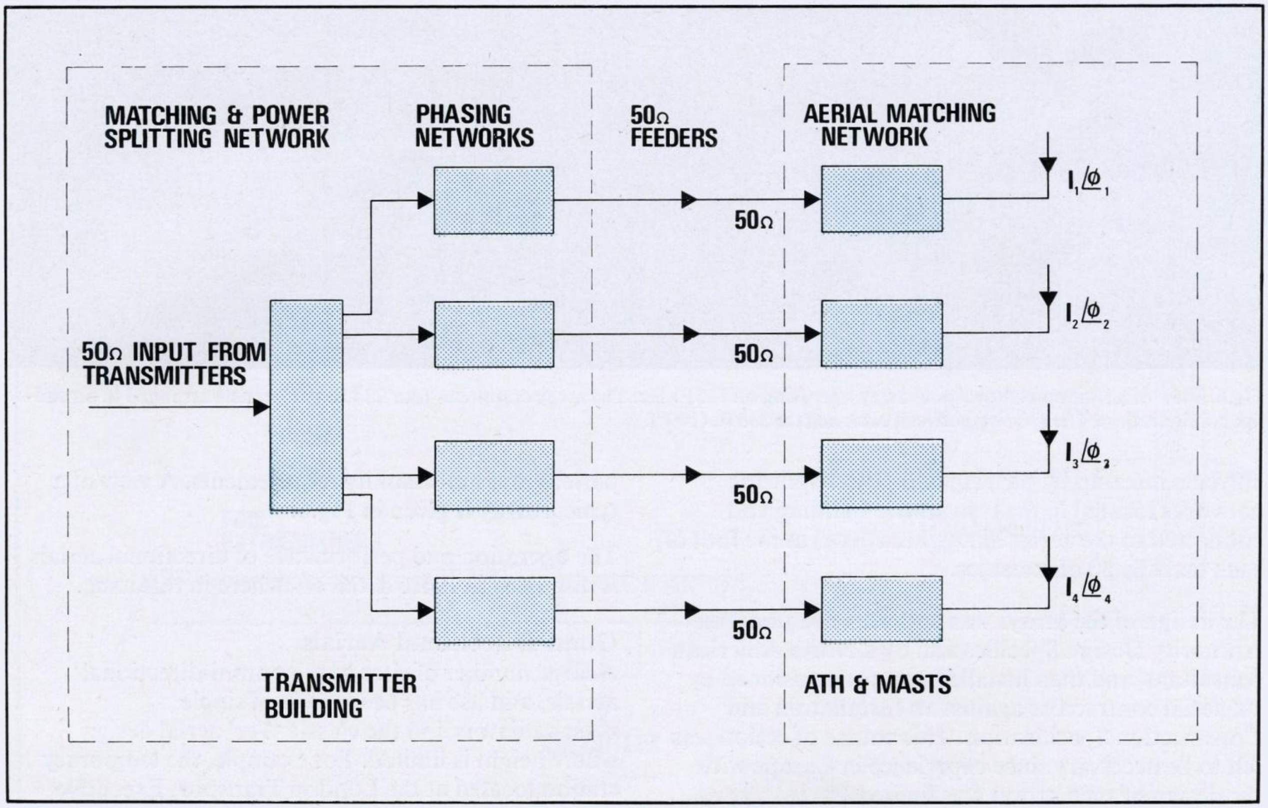


Fig.5. Basic schematic of feed arrangements to a typical four-mast directional array. Each radiator is impedance matched to 50 ohms in the Aerial Tuning Hut (ATH) at its base, due account being taken of mutual impedances. The required phase and amplitude current distribution is set-up by phasing and power splitting networks located in the transmitter building.

Fig.6. View of a four mast directional array operating on 1151 kHz. The array comprises four 234 ft. (97°) masts arranged in an end-fire configuration. The spacing between each mast is 238 ft. (100°).

currents is set-up by phasing and power splitting networks located in the transmitter building and connected to the aerial tuning huts (ATH) at the foot of each mast by 50 ohm cables.

The design of the arrays was undertaken against an Authority Design Specification by a North American consultant, and then installed and commissioned by UK aerial contractors against an Installation and Construction Specification. This course of action was felt to be necessary since experience in Europe with the design of such arrays was limited.

Several arrays have now been installed and are successfully in service, having met the radiation pattern and null stability requirements. A view of a typical array is given in Fig.6.

The operation and performance of directional aerials is discussed in more detail elsewhere in this issue.

Omni-Directional Aerials

A large number of sites require omni-directional aerials, and use has been made of single mast-radiators and the classic 'Tee' aerial design where height is limited. For example, the temporary station located at the London Transport Executive power station at Lots Road, Chelsea, uses a 'Tee' aerial extending between the two 90 m chimneys and provides a temporary two-channel service to the

London area on 557 kHz and 719 kHz, using 1 kW and 0·5 kW transmitter powers respectively.

At existing and future omni-directional sites, mast radiators of between 60° and 90° in electrical height, dependent on economic and efficiency considerations, have been used. These have demonstrated efficiencies ranging from 70% to 90% when used with a 120-wire radial earth system.

Power Supply Arrangements

Power supply arrangements have been made extremely simple, each station being fed from a single-phase or three-phase supply with up to 25 kVA capacity. Stand-by diesel generators have not been provided as it is anticipated that the reliability of the Electricity Board Supply will be satisfactory. A further feature of the supply arrangements is that automatic voltage regulators have been omitted, since the transmitter plant was capable of operating satisfactorily with up to 10% reduction in mains voltage.

One consideration in the design of directional stations was the feasibility of bringing the electricity supply on overhead poles to the transmitter building since, although this would be economic, there was the possibility of interference, due to re-radiation, to the

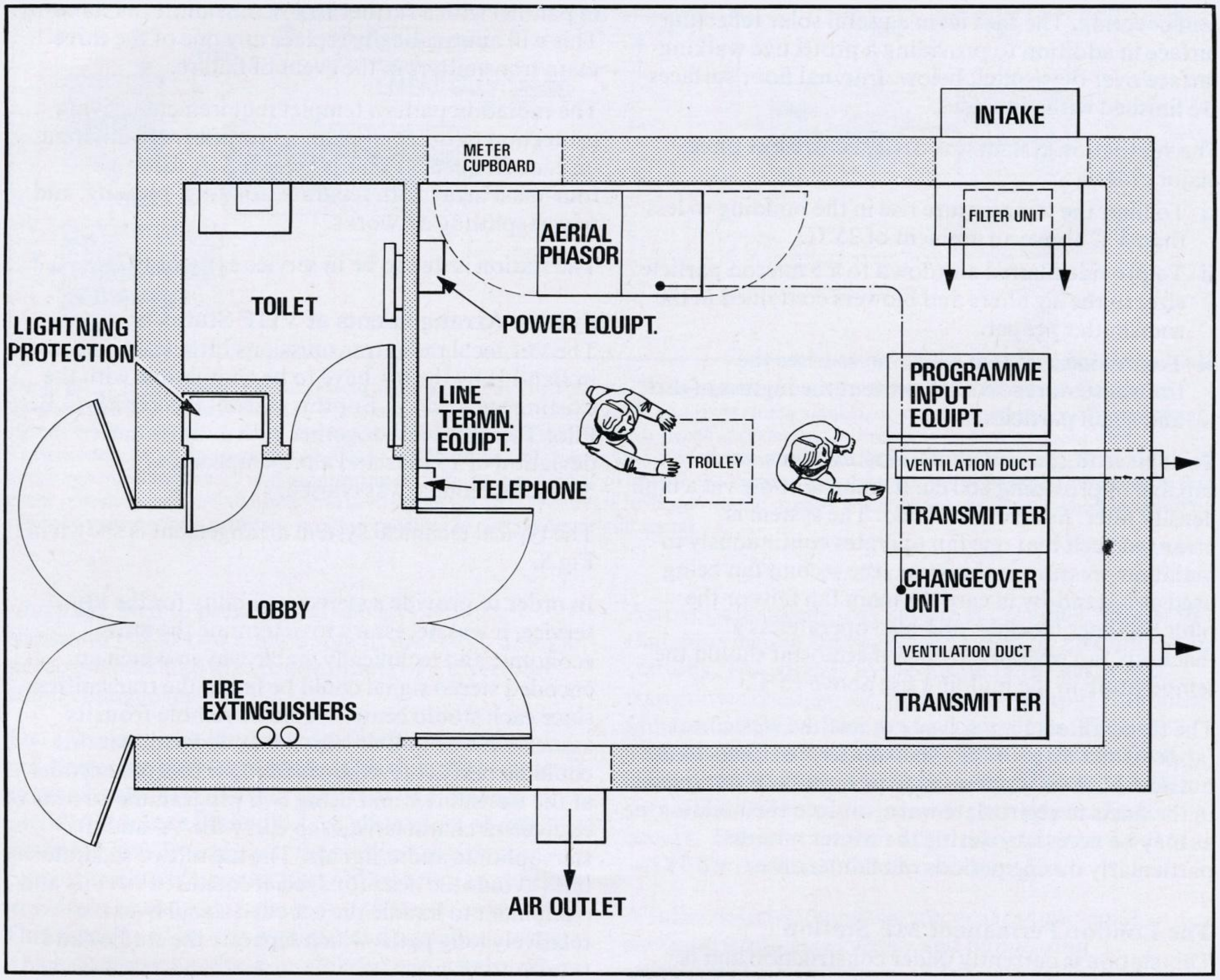


Fig.7. Typical equipment layout at a medium wave transmitting station. The transmitting equipment is housed in a building approximately 6 m × 4·5 m × 3·5 m high. Ventilation is provided from dual fans, one operating continuously to maintain slight pressure in the room, the second being used as a stand-by.

nulls of the aerial pattern. Providing the support poles were short in electrical length (less than 20° or so) it was decided this would not occur, and consequently the supply has been routed overhead.

Building and Ventilation

The equipment at 1 kW and 2 kW stations is housed in a building approximately 6 m x 4·5 m x 3·5 m high. A typical layout of equipment is shown in Fig.7.

The buildings are of traditional load-bearing cavity-wall construction. The walls are built directly on a reinforced concrete ground slab and support a flat roof of precast concrete units. Roof finish consists of asbestos cement tiles laid in bitumen on an asphalt roof covering. The tiles form a useful solar reflecting surface in addition to providing a protective walking surface over the asphalt below. Internal floor surfaces are finished with vinyl tiles.

The ventilation system was designed to meet three major criteria:

i To limit the temperature rise in the building to less than 5°C above an ambient of 25°C.

ii To provide filtered air (down to a 5 micron particle size) to the air filters and blowers contained in the transmitter proper.

iii To provide a system which pressurises the transmitter area so as to prevent the ingress of dirt and small particles.

To achieve this, a unit containing two fans, each capable of providing 800 cu. ft./min. air flow via a high density filter, has been installed. The system is arranged such that one fan operates continuously to maintain pressure in the room, the second fan being used as a stand-by in case the main fan fails or the filter becomes blocked, and also operates as a 'back-up' fan operated from a thermostat should the temperature in the building rise above 25°C.

The transmitters themselves exhaust the waste heat (approximately 3 kW per transmitter) via ducts to the outside. Manually operated flaps have been provided in the ducts to recirculate warm air into the building as may be necessary during the winter months, particularly during periods of maintenance.

The London Permanent MF Station

This station is currently under construction and is designed to provide two services, one on 1151 kHz and the other on 1546 kHz, from a common four-mast directional aerial system.

The site is approximately 12 miles north of London, and will provide maximum radiated powers of 20 dBkW and 14 dBkW towards the city centre. It should perhaps be noted here that the effective radiated power of directional arrays is expressed in dB relative to 1 kW as radiated from a hypothetical short vertical monopole radiating over a perfectly conducting flat ground plane. 'Zero' dB is equivalent to an unattenuated field of 186 mV/m at 1 mile range.

The transmitter equipment is to be housed in a building approximately 20 m by 8 m by 4 m high, and will comprise two 10 kW transmitters in a main and stand-by configuration for the 1151 kHz channel. For the 1546 kHz service three 10 kW transmitters will run in parallel with a further 10 kW transmitter as stand-by. This will automatically replace any one of the three main transmitters in the event of failure.

The radiation pattern templet requirements, giving protection to other co-channel stations, are different on each frequency. This is achieved by using a four-mast array with separate isolating, phasing, and power splitting networks.

The station is due to be in service early in 1975.

System Arrangements at VHF Stations

The VHF local radio transmissions broadcast in stereo in Band II by the IBA have to be compatible with the existing BBC service. For this reason, the Zenith-G.E. Pilot Tone System[1], together with a maximum deviation of 75 kHz and a pre-emphasis of 50 microseconds, was chosen.

The typical technical system arrangement is shown in Fig.8.

In order to provide a stereo capability for the VHF service, it was necessary to determine the most economic and technically viable way in which an encoded stereo signal could be fed to the transmitters, since each studio centre would be remote from its associated transmitter site. It was decided that this could be best achieved by locating the stereo encoder at the transmitter and using two programme circuits of equivalent characteristics to carry the 'A' and 'B' stereophonic audio signals. The use of two separate lines avoids the need for special equalised circuits and equipment to handle the encoded signal over the relatively long paths which separate the studios and transmitting sites.

The incoming signals from each line are fed to separate limiters having identical characteristics and

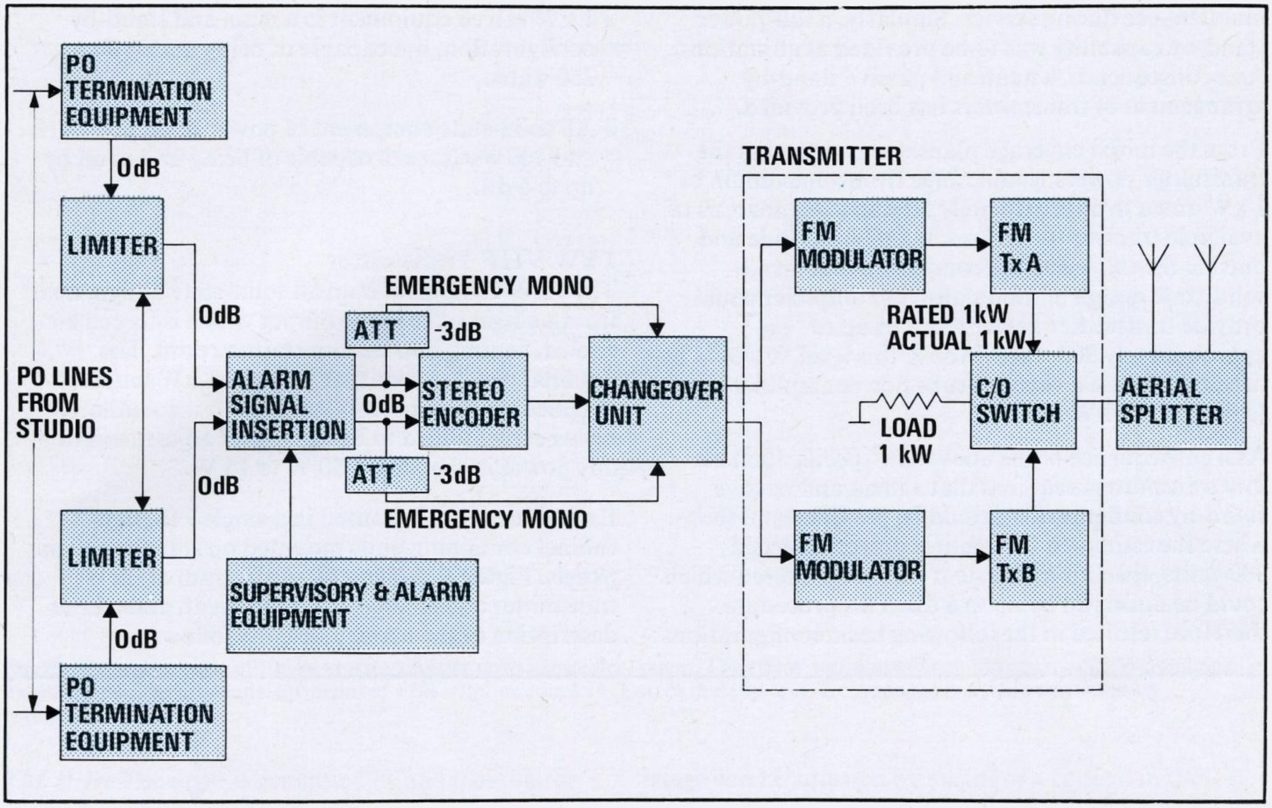


Fig.8. Block schematic of typical system arrangement at VHF stations. The programme path from the studio centre consists of two lines of equivalent characteristics. These are used to carry either the left and right stereo signals, or mono, on each line. The incoming signals are then fed to identical limiters and then to the transmitter via a stereo encoder and a three-way audio switching unit. Transmitters typically comprise a 1 kW or 100 W main and passive stand-by arrangement, feeding a circularly polarised 'transmitting' aerial system. Supervisory and monitoring equipment is provided to initiate the necessary changeover to the reserve conditions in the event of failure and also to insert an alarm signal which is broadcast 'over-air' to the studio. The encoder may be switched to mono or stereo from the studio using the programme lines to carry a command signal.

which are used to prevent over-deviation of the transmitter. The two limited signals are fed to a single stereo encoder and also to the inputs of a three-way audio changeover unit.

The encoder is not duplicated; suitable supervisory arrangements have been made such that the encoder is automatically by-passed in the event of either an encoder failure, a limiter failure, or the loss of one incoming line. In addition, the studio has a remote control facility (using the Post Office programme lines) to switch the encoder from mono to stereo as required. This is achieved by using an in-band signalling system which comprises a phase-modulated sub-carrier of 14·0 kHz, at a level of −24 dBm which is appropriately coded at the studio and decoded at the transmitter to activate the mono/stereo switching.

An over-air supervisory system is provided, similar to that described in the previous section on medium wave stations. This signals to the studio in the event of a transmitter changeover, a programme input equipment fault, or a PO line fault at the transmitter. The VHF system is similarly capable of sending up to six fault conditions, and operates by inserting a coded 14 kHz sub-carrier into the programme path when a fault occurs. The sub-carrier is approximately at a level of −34 dBm, and is of 0·5 second duration.

A fuller description of the VHF programme input equipment and supervisory and monitoring arrangements is contained elsewhere in this issue.

As in the case of medium wave stations, a main design requirement was high reliability and ease of

maintenance during service. Similarly, a full-power stand-by capability was to be provided at all stations. As a consequence, a main and passive stand-by arrangement of transmitters has been provided.

From the initial coverage plans it was clear that the transmitter powers would range from a maximum of 1 kW down to approximately 50 watts. An analysis of available transmitter designs, from both inside and outside the UK, led to the conclusion that an all solid-state design of modulator and amplifier could provide transmitter power levels of up to approximately 300 watts. Above this level, it would be necessary to use a vacuum-tube power amplifier stage to reach the 1 kW level.

As a consequence of the above, the specification of VHF transmitters required that a main and passive stand-by configuration should be provided and that where the estimated transmitter power exceeded 300 watts, then a 1 kW system was to be offered which could be underrun by up to 6 dB. This procedure therefore resulted in the following basic configurations:

i 1 kW valved equipment in a main and stand-by configuration, but capable of being underrun to 250 watts.

ii All solid-state equipment of power levels 300 watts and 100 watts, each capable of being underrun by up to 6 dB.

1 kW VHF Transmitter

The 1 kW equipment is an all solid-state design, apart from a single valve in the output which is forced air cooled, venting into the transmitter room. The nominal maximum output power is 1 kW but, as specified, the equipments supplied to the Authority have been modified to be capable of adjustment to any power in the range 250 W to 1 kW.

Each transmitter is housed in a single 7 ft. high cabinet containing units mounted on standard 19 in. panels. Figure 9 shows a block diagram of the transmitter and changeover equipment, and a brief description of the major sub-units follows.

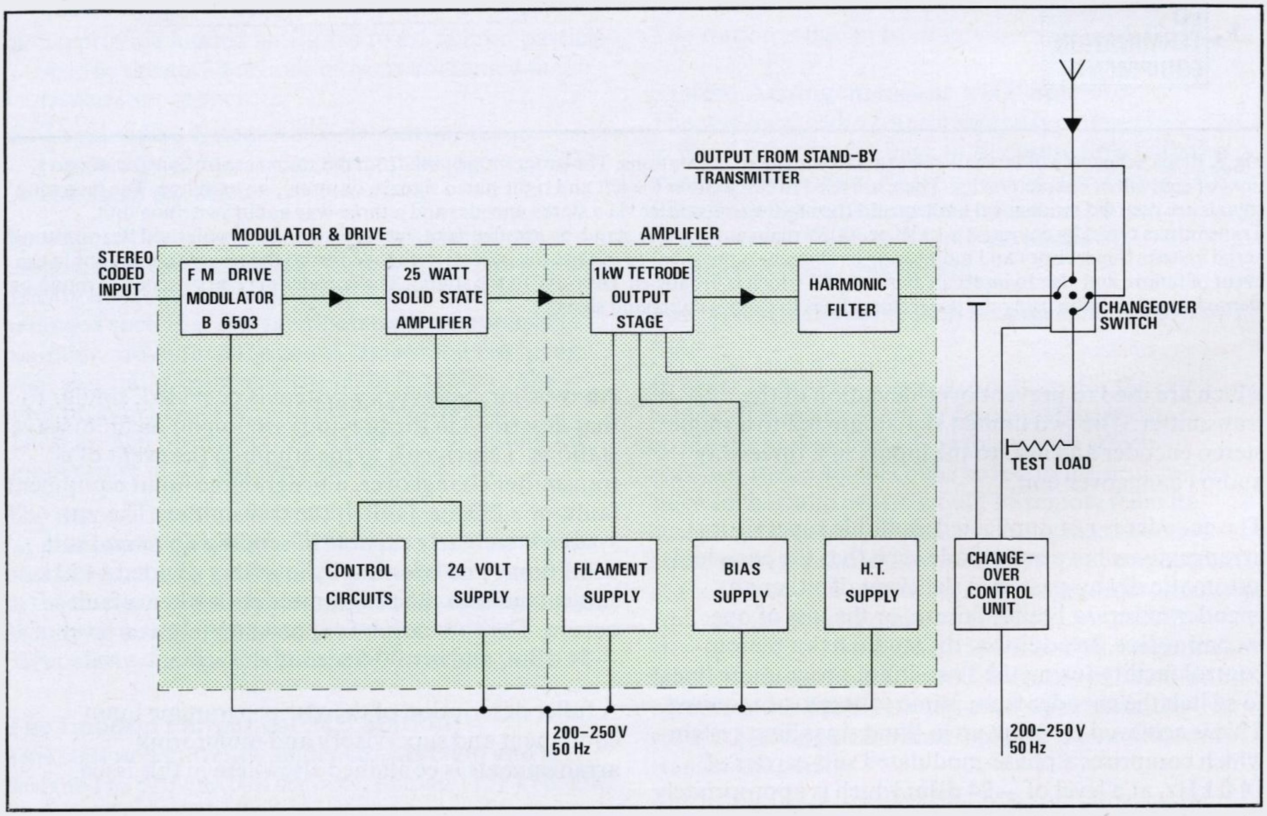


Fig.9. Block schematic of the 1 kW VHF transmitter comprising an all solid-state modulator and drive unit, followed by a vacuum tube tetrode power amplifier stage.

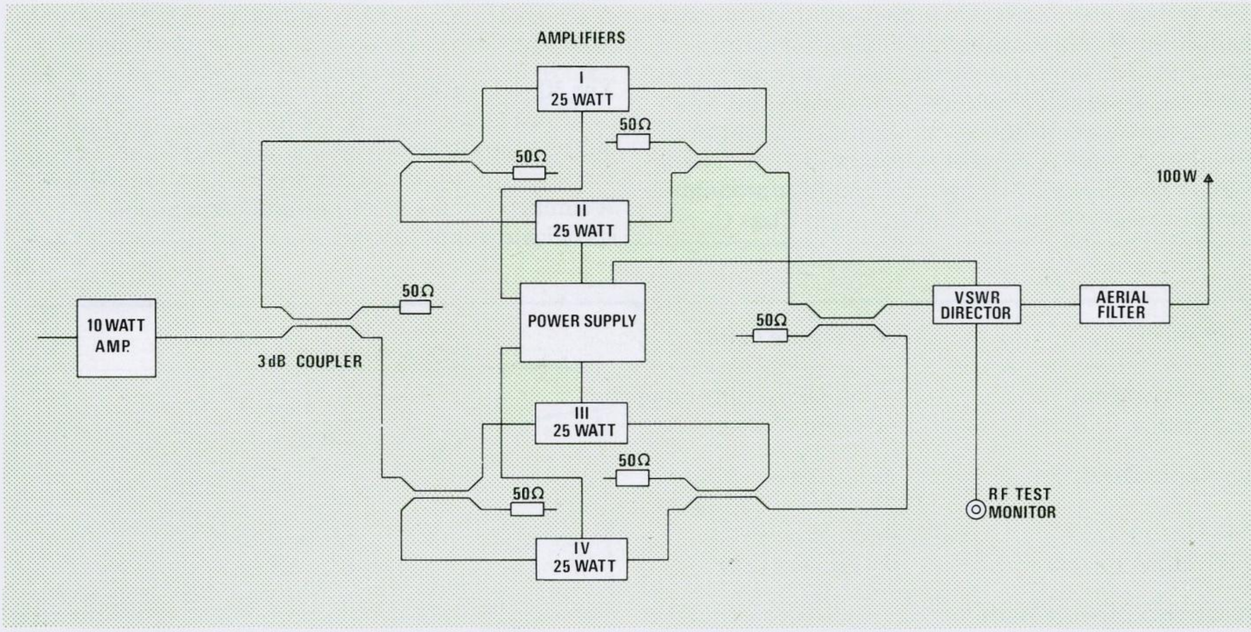


Fig.10. Block schematic of 100 W VHF transmitter power amplifier system. The 100 W VHF amplifier comprises four 25 W amplifier modules operated in parallel by means of 3 dB stripline couplers. Two of these systems are arranged in a main and stand-by configuration.

FM Drive The drive is generated by an LC oscillator running at one third the final output frequency and modulated by a varactor diode. A sample of the output of this oscillator is mixed with that of two crystal-controlled reference oscillators, one 500 kHz above fo/3 and the other 500 kHz below fo/3. The outputs of these mixers are demodulated by means of an aperiodic discriminator, and the two signals are compared in a dual input comparator. The resulting control voltage is applied to a varactor diode which maintains the frequency of the LC oscillator at the correct value. Among the advantages of this system are a minimum of centre frequency drift due to modulation, and the impossibility of the frequency becoming locked to some incorrect value, which can occur in some systems. The output is multiplied by three in a transistor multiplier and is amplified to the 0·5 watt level. A full description of the drive appears in Ref. 2.

Drive Amplifier A transistor Class 'C' amplifier is used to raise the power level to 15 watts.

Output Stage The power output is obtained from a single valve, a tetrode type 4CX1000A, operating in Class C. The output is taken via a π-matching network and a low-pass coaxial filter is used to reduce the spurious radiation. The actual output power of this stage can be adjusted by means of a control in the screen-grid voltage supply. This allows any power in the range 250 watts to 1 kW to be obtained.

Automatic Changeover Should the output power of the main transmitter fall by more than 2 dB, or should the modulator fail, the automatic changeover unit will switch off the main transmitter, switch on the stand-by equipment, and operate a coaxial switch in the output feeder to connect the stand-by equipment to the aerial. There is a delay of some seven seconds between a fault occurring and the changeover taking place to allow for short duration mains faults and to give the *three shot reset system*, operating upon the power supply overload trips, time to act. A full-power test load is provided to allow the transmitter not connected to the aerial to be tested and maintained. Apart from the supplies to the output valve, both transmitters are operating continuously. However, due to the warm-up time of the output valve, there is approximately three minutes delay between changing over to the reserve transmitter and the programme being restored.

100 W and 300 W Transmitters

The 100 W and 300 W transmitter configurations are similar in principle to the 1 kW design, comprising a

main and stand-by drive and amplifier with automatic changeover should the main chain fail. The drive modulator and intermediate amplifier are identical to those used in the 1 kW system. A single 100 watt power amplifier consists of four identical 25 watt modules operated in parallel by means of 3 dB stripline couplers. Each individual amplifier module comprises a BLY94 transistor operating in Class C.

A schematic of a 100 W amplifier arrangement is given in Fig.10.

The 300 watt arrangement operates on precisely the same principles, with the exception that to obtain the 300 watt power level, eight parallelled rf amplifier modules are required, each producing about 40 watts. A summary of the VHF transmitter equipment specification is as follows:

Parameter	*Acceptance Limits*		*Remarks*
Audio Frequency Response	±0·5 dB over the range 40 Hz to 15 kHz		
Harmonic Distortion	*Deviation*		
	75 kHz	*100 kHz*	
40 Hz to 100 Hz	0·6%	0·8%	
100 Hz to 15 kHz	0·4%	0·6%	
Audio Signal/Noise Ratio*			
Random FM Noise	>60 dB unweighted >66 dB weighted**		Measured with respect to 75 kHz deviation
Random AM Noise	>50 dB unweighted		
Hum and Synchronous FM Noise	>60 dB		
Hum and Synchronous AM Noise	46 dB		
Unwanted AM due to FM	40 dB below carrier level when transmitter is deviated to 75 kHz		
Change of Centre Frequency with modulation	2 parts in 10^6		When subjected to a deviation of 100 kHz
Carrier Frequency Stability	20 parts in 10^6		
Pre-emphasis	50 µs ± 2 µs		
Additional Parameters for Stereo			
Linear Crosstalk between left and right channels (including encoder)	40 Hz to 300 Hz, oblique segment 6 dB/octave 300 Hz to 4 kHz, >34 dB 4 kHz to 15 kHz, oblique segment 6 dB/octave		
Audio Signal-to-Noise Ratio			
Random FM Noise	66 dB weighted 60 dB unweighted		Measured with respect to 75 kHz deviation

* *Signal-to-noise ratio has been expressed as a ratio between rms signal to rms noise.*
** *Weighting network in accordance with CCIR recommendation No. 468, Report No. 496.*

Transmitter Modulation Level
The stereo programme level is controlled at the studio such that the maximum audio signal presented to the programme chain is at a level of +8 dBm, either as a sum signal or on either of the A or B lines. It is inevitable that, for a small proportion of the time, this level will be exceeded, and therefore, to prevent over-modulation of the transmitters, limiters are inserted in the programme path. It is undesirable that the limiters are in operation excessively, and a 'guard-band' of 2 dB has been provided. This is achieved by arranging the onset of the limiting action to be at a level of +10 dBm, and setting the transmitter deviation to 54·2 kHz for a +8 dBm signal level.

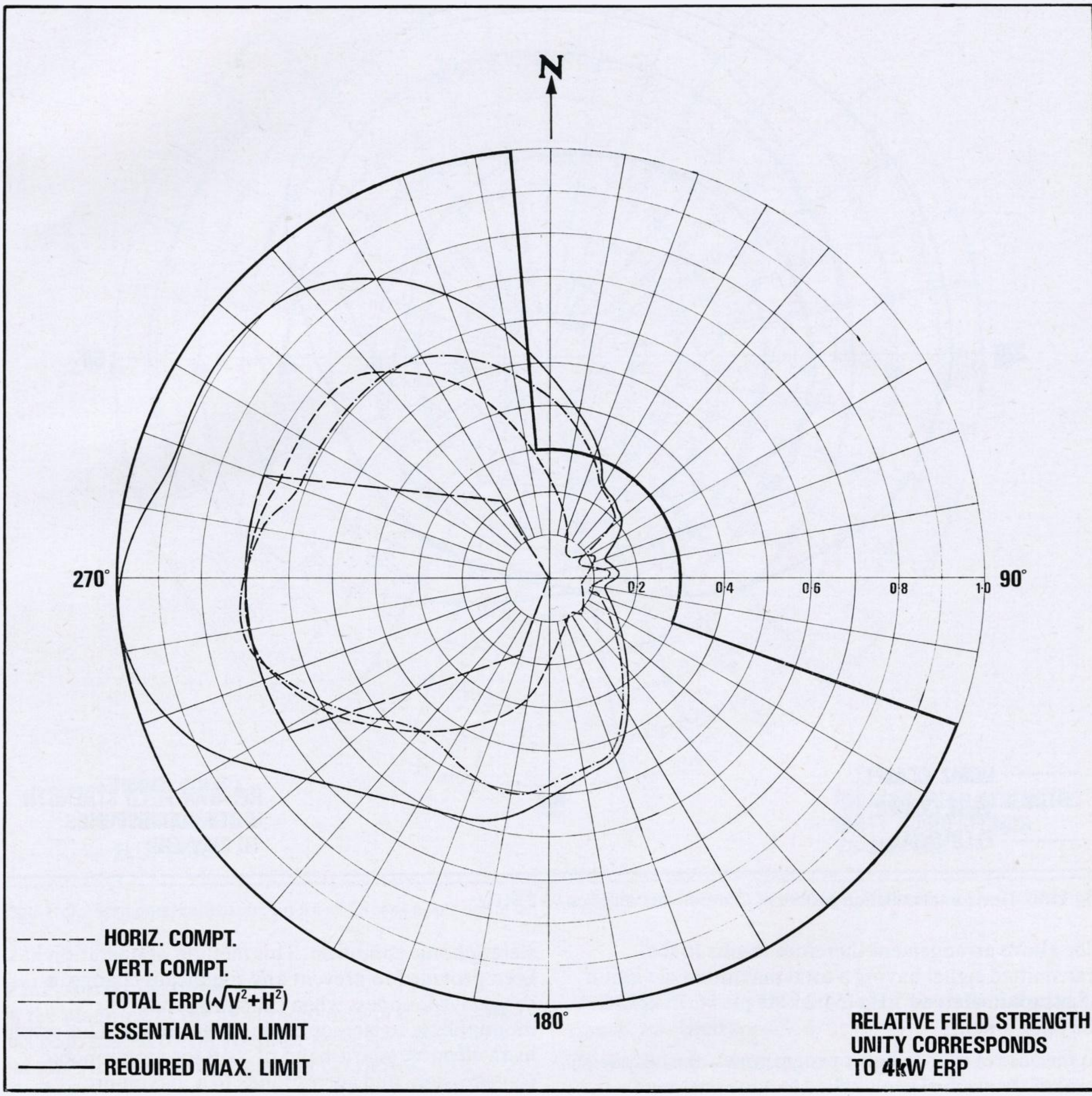


Fig.11(a). Horizontal radiation pattern and templet of Glasgow VHF aerial.

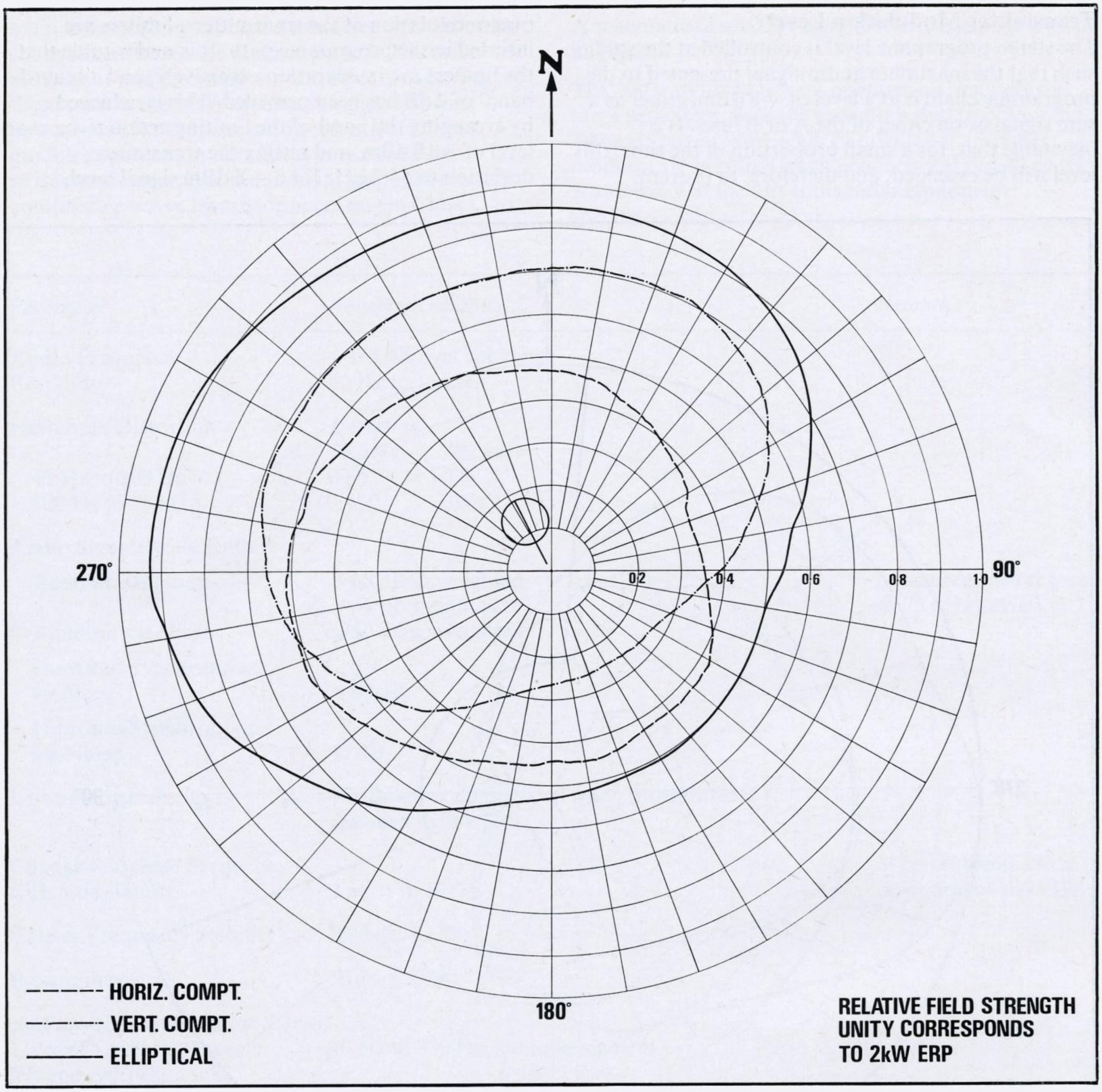


Fig.11(b). Horizontal radiation pattern of Croydon VHF aerial on 95·8 MHz.

The above arrangement therefore results in the transmitted signal having a total maximum deviation of approximately 61 kHz (54·2 kHz plus 6·75 kHz for the pilot tone).

In the case of monophonic programmes, the output level of the studio is controlled to a maximum of +5 dBm, that is 3 dB below the maximum stereophonic condition. This method of operation has been provided to prevent any significant change in subjective loudness when changing from monophonic to stereophonic programmes. This results in an effective guard-band of 5 dB for monophonic transmission, and corresponds to a maximum deviation of 38·4 kHz.

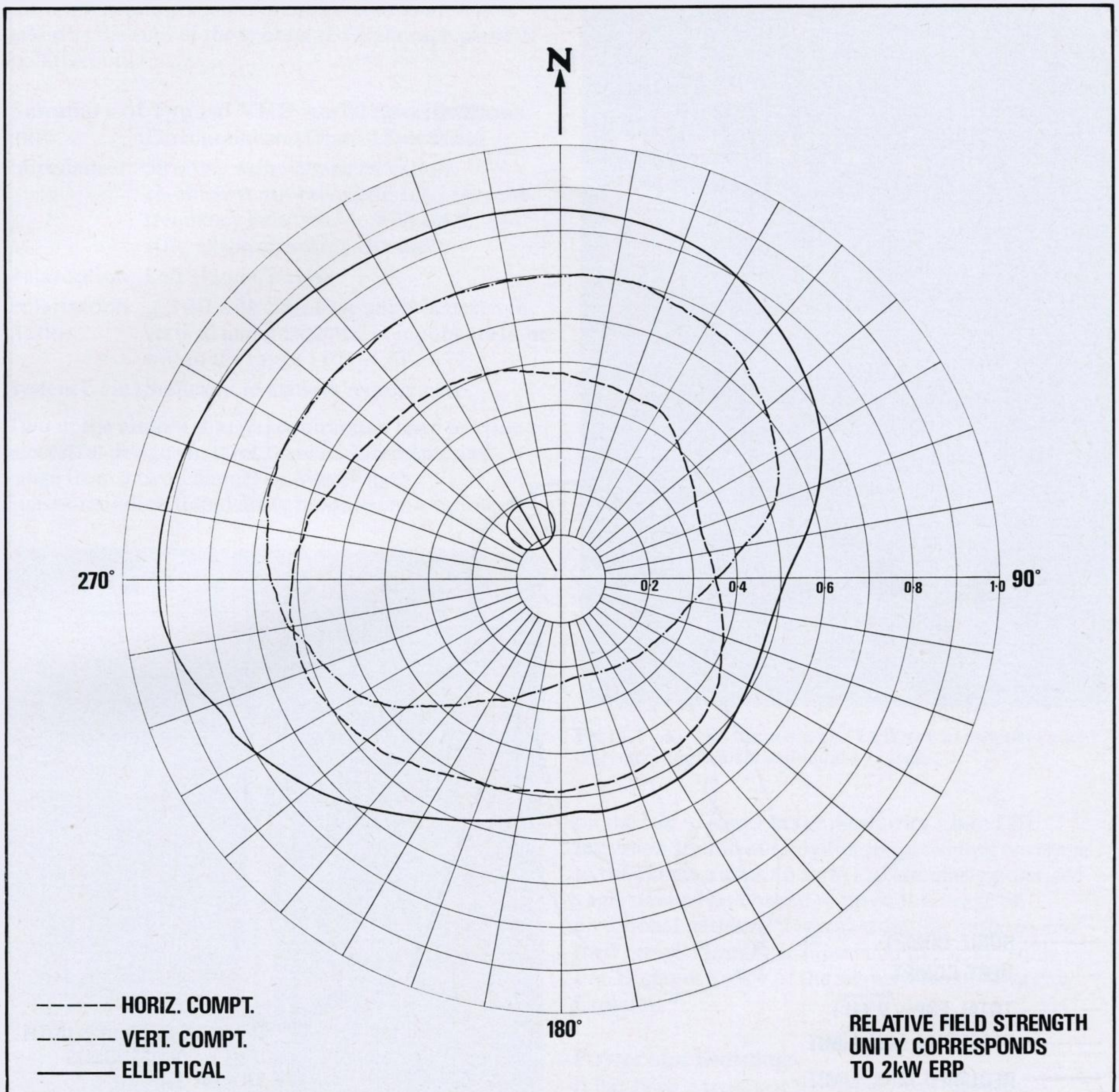


Fig.11(c). Horizontal radiation pattern of Croydon VHF aerial on 97·3 MHz.

VHF Aerial Systems

In the planning of the local radio network, emphasis has been placed on the needs of those listeners using portable transistor receivers and car radios. As a result, the transmission of a vertically polarised component of field, as well as a horizontal component to satisfy listeners with outside horizontally polarised aerials, has been specified.

The maximum advantage to be gained from radiating a mixed polarised signal varies from between 6 dB for car reception and about 12 dB for reception at open

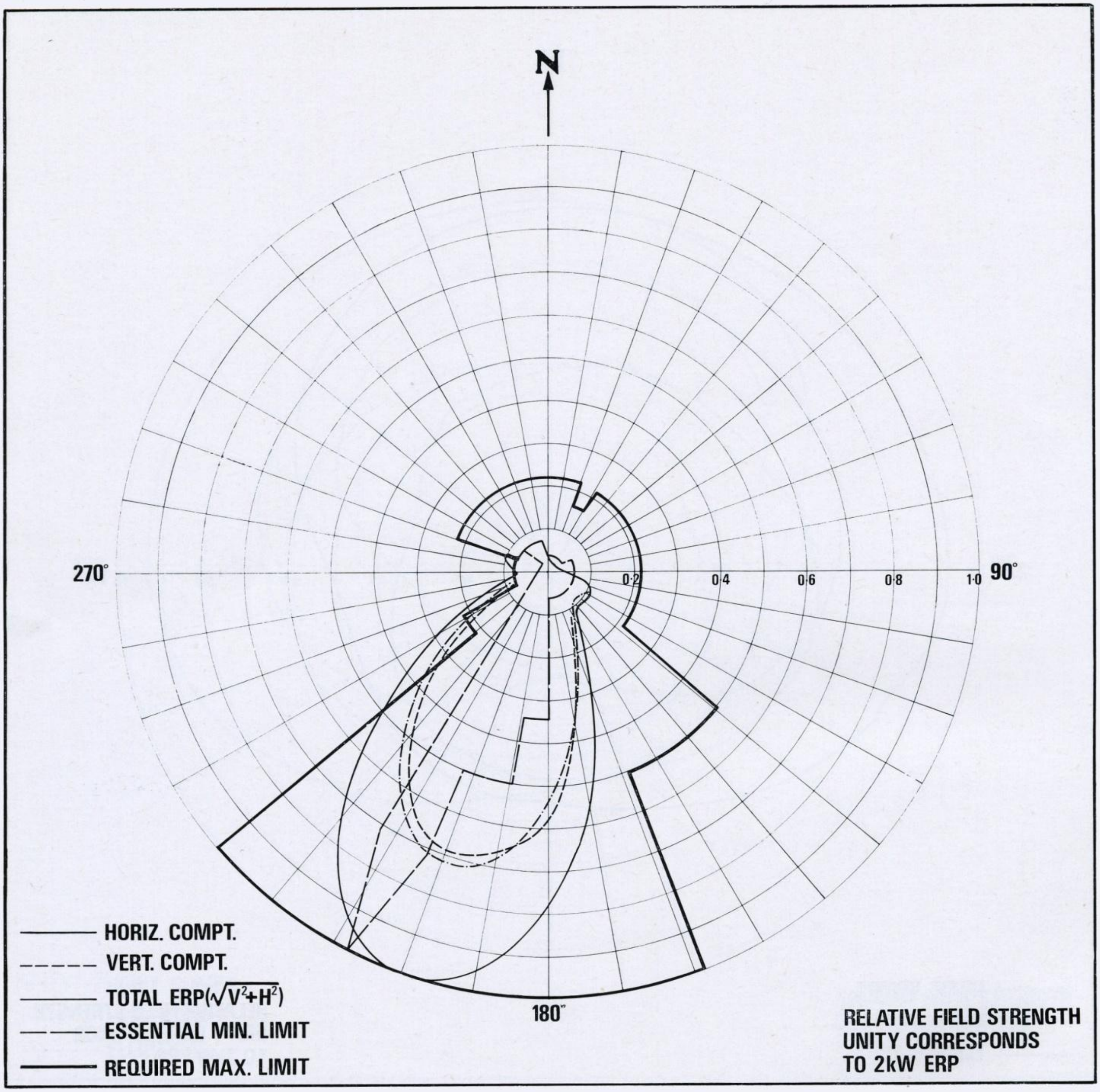


Fig.11(d). Horizontal radiation pattern and templet of Birmingham VHF aerial.

outdoor 'picnic' sites[3]. However, it should be noted that in urban areas, and particularly inside houses, scattering of the signal can result in a randomly polarised signal and little advantage is obtained.

In view of the foregoing, the specification for VHF aerials calls for the provision of circularly polarised aerial systems. A brief description of circular polarisation theory is given in Appendix 1.

The required effective radiated powers range from 5 kW down to about 50 watts (*see Table 1*) with possibly even lower powers where only small areas are to be served. It should be noted that the erp of

stations radiating signals of mixed polarisation is taken as the sum of those obtained from each plane of polarisation.

Summary of Typical VHF Aerial Specifications

HRP:	Directional and Omni-Directional
Impedance:	50 ohms with voltage reflection co-efficient not exceeding 15% over the frequency band 94·5 to 97·5 MHz, and 10% at the operating channel.
Polarisation:	Left Hand Circular.
Polarisation Ratio:	±3 dB with the phase angle between the vertical and horizontal components to be within the range 110° to 70°.
System Gain:	Sufficient to achieve required erp.

Two of the major UK aerial contractors have provided successful designs to meet these requirements and range from a two-channel six-wavelength quasi-omni-directional array mounted as a cantilever

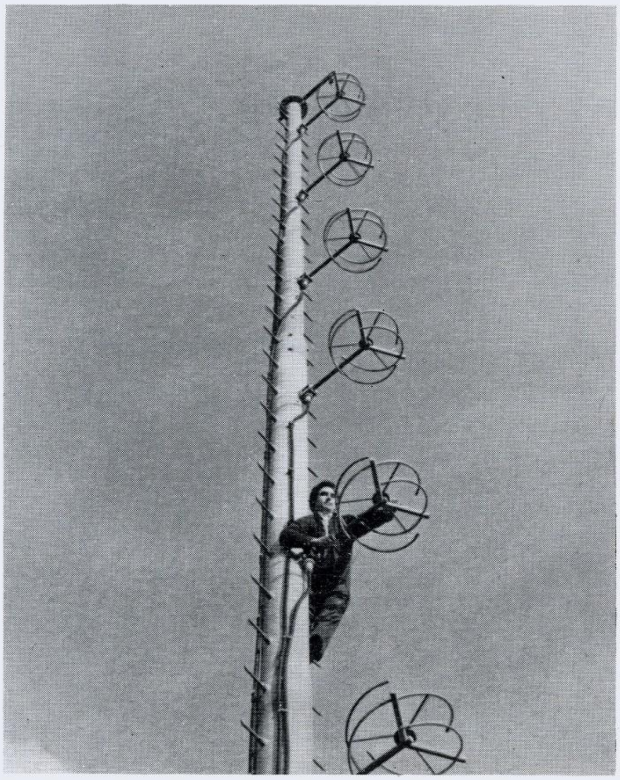


Fig.12. The Croydon VHF two-channel circularly polarised transmitting aerial serving London. It comprises six tiers of circularly polarised elements spaced one wavelength apart. The array is mounted on a cantilever pole surmounting the existing 500 ft. tower at Croydon.

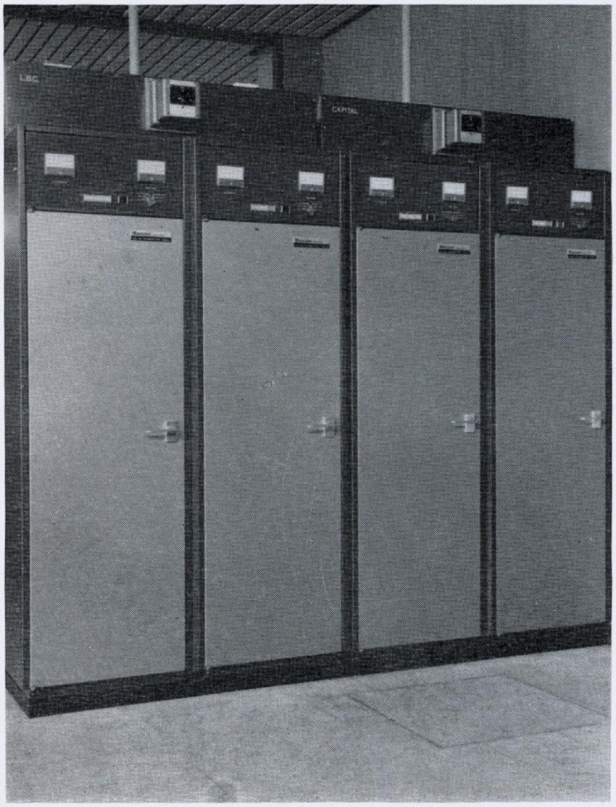


Fig.13. This shows the two sets of 1 kW VHF transmitters, each pair operating in main and stand-by mode.

on the 500 ft. tower at the Authority's Band III television station at Croydon for providing coverage to the London area, to arrays of circularly polarised yagis stacked and bayed to provide a range of directional patterns. Typical radiation patterns and their templet limits are illustrated in Fig.11, while Fig.12 shows a view of the six-wavelength array at Croydon.

Power and Buildings

It has been possible at the majority of stations covering the larger conurbations to co-site the VHF transmitters with television main or relay stations. As a consequence, it has been possible to install the ILR transmitting equipment into available space in existing buildings, and also to integrate the necessary electrical supply requirements with the existing facilities.

A typical layout of the transmitting equipment is illustrated in Fig.13, which shows the dual-channel installation at Croydon.

At future low-power stations (less than 300 watts transmitter power), it is envisaged that proprietary industrial buildings will be used, similar to those used at low-power UHF television relay stations[4].

Conclusions

The construction of the first phase of the Independent Broadcasting Authority's local radio stations is now nearing successful completion and, from the initial

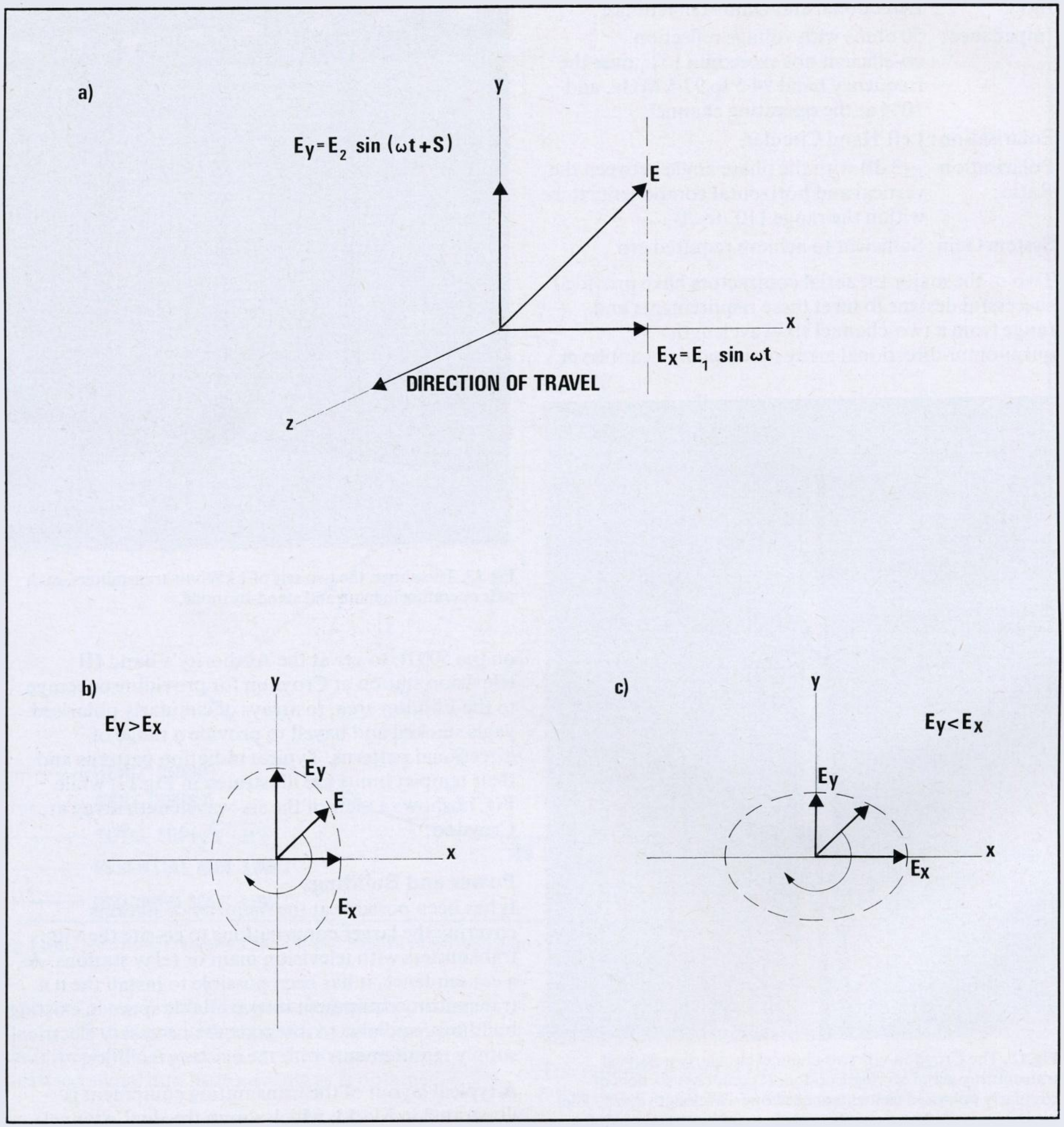


Fig.14. An elliptically polarised wave may be represented by two mutually perpendicular linear waves as shown here.

operating statistics, a satisfactory level of reliability has been achieved. Looking to the future, the Authority's engineers are in close contact with possible new developments and usage of the radio medium in such areas as methods for providing traffic information, noise reduction systems for FM broadcasts, and quadraphony.

Appendix

BASIC THEORY OF CIRCULAR POLARISATION

It is necessary to firstly consider elliptical polarisation, since it is convenient to regard the other types of polarisation, circular, slant or linear, as special examples of the more general elliptical case.

Referring to Fig.14, the general case may be

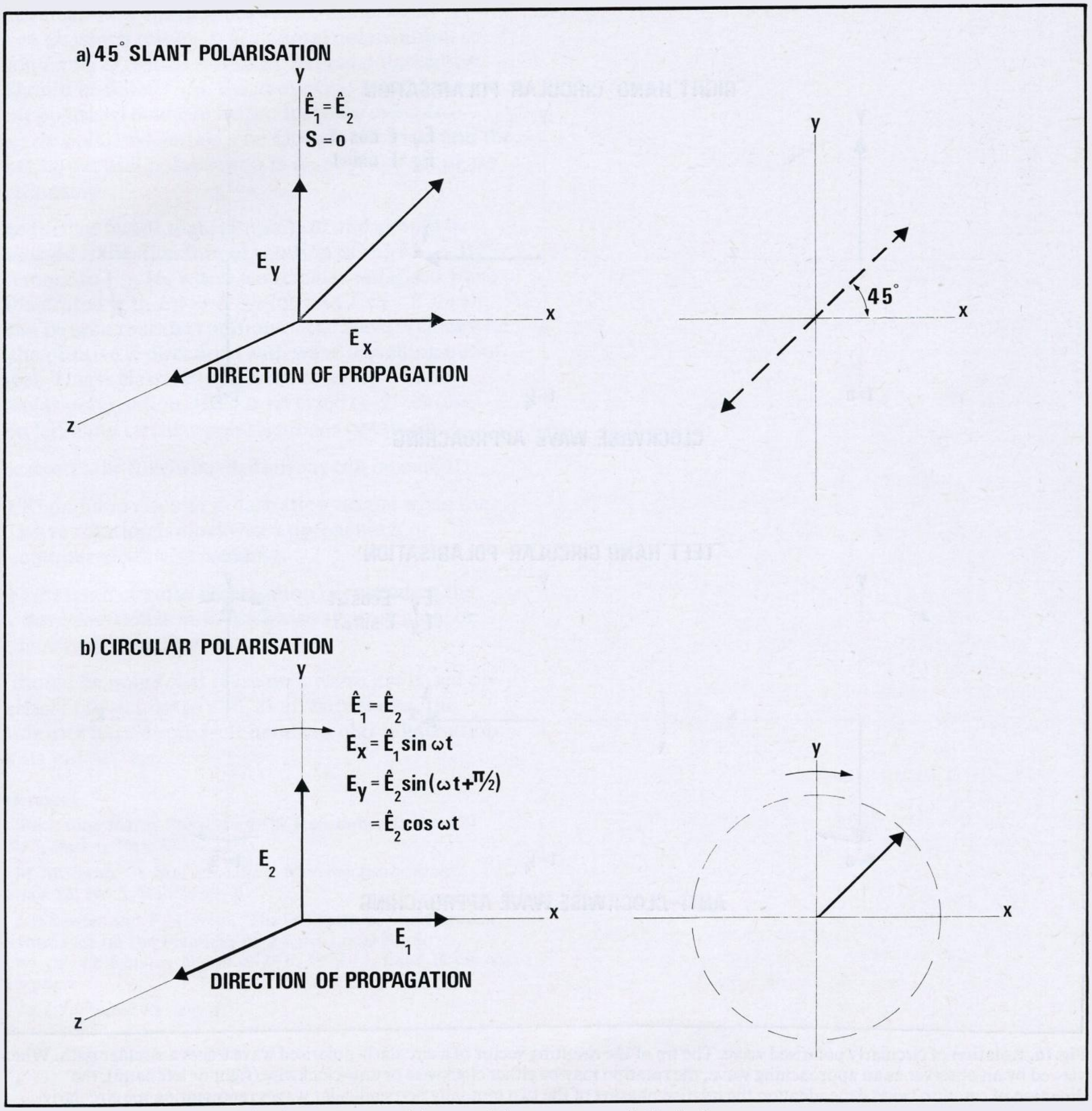


Fig.15. Slant and circular polarised waves are special cases of the more general elliptical case.

represented by two mutually perpendicular linear waves which are travelling in the Z direction and varying with time in accordance with the expressions,

$$Ex = E_1 \sin \omega t$$
$$Ey = E_2 \sin (\omega t + S)$$

where S is the phase difference between the two waves.

This results in a wave propagating in the Z direction with the tip of its resulting electric vector, E, tracing an elliptic path. Therefore, when viewed from the Z direction, this results in an ellipse with a major axis of

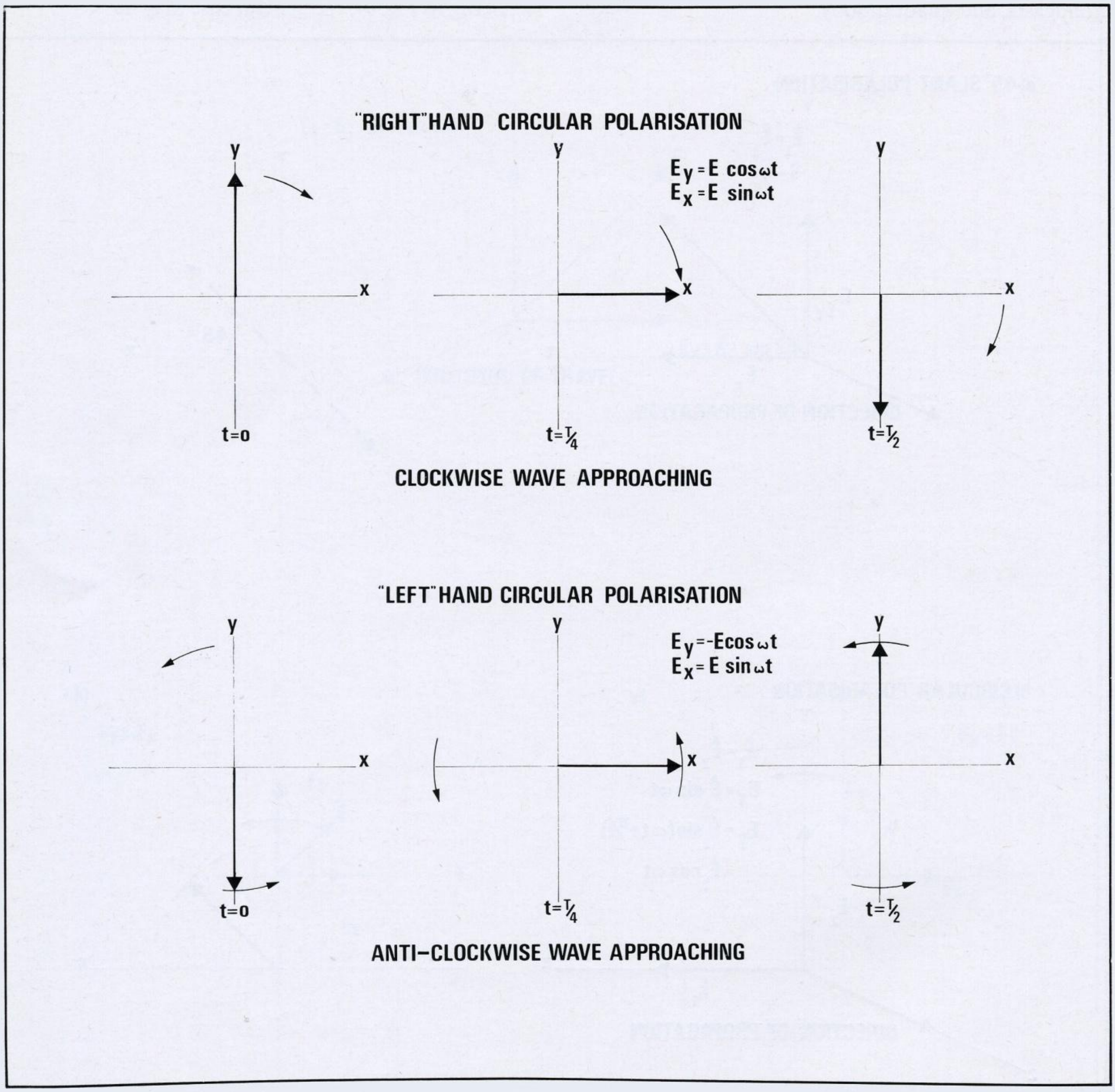


Fig.16. Rotation of circularly polarised wave. The tip of the resulting vector of a circularly polarised wave traces a circular path. When viewed by an observer as an approaching wave, the rotation may be either clockwise or anti-clockwise (right or left hand), the direction of rotation being dependent on the relative phasing of the two mutually perpendicular waves representing the circularly polarised field.

E_1 or E_2, depending on the relative magnitudes. It is now possible to consider some examples of specific interest, such as forty-five degree slant polarisation and circular polarisation.

These are indicated in Fig.15 and occur when $E_1 = E_2$, $S = O$ and $E_1 = E_2$, $S = \pi/2$ respectively.

Of course, some other special cases occur when $Ey = O$, which results in horizontal polarisation, or when $Ex = O$, which results in vertical polarisation. It should be noted from the above that a circular or slant polarised field can be produced by using two linearly polarised aerials, one radiating vertical and the other horizontal polarisation in an appropriate phase relationship.

One further factor that is important and should be discussed is the direction of rotation of the wave. By reference to Fig.16, where a circularly polarised wave is illustrated with $Ey = E \cos \omega t$, and $Ex = E \sin \omega t$, it can be seen that the rotation of the wave is clockwise in the positive Z direction (with wave travelling out of page). This is classically referred to as right hand circular polarisation. If Ey is reversed ($-E \cos \omega t$), then left hand circular polarisation is obtained.

Therefore, the following definitions can be made:

(a) Right hand circular polarisation occurs when the wave rotation is clockwise approaching, or counter-clockwise receding.

(b) Left hand circular polarisation occurs when the wave rotation is anti-clockwise approaching, or clockwise receding.

It should be noted that these definitions are based on classical physics usage and, as already stated, the Authority has adopted left hand circular polarisation for its VHF service.

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4. *IBA Technical Review*, **4.**

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Programme Input and Control Equipment for ILR Transmitting Stations

by P A Crozier-Cole

Synopsis
The design of the programme input and control equipment at VHF and MF ILR stations is discussed, with reference to the technical and the operational requirements. Following a consideration of the programme path structure, the signal processing arrangements are described, including the stereo coder which is installed at the VHF transmitting stations. The need to switch between mono and stereo at will from the studios gives rise to the need for limited remote control, which is achieved by a novel form of in-band coded tones. A similar system is used to signal alarms to the studio, using the over-air path itself from transmitter to studio.

INTRODUCTION

At ILR transmitting stations, programme input equipment is provided for signal processing purposes before transmission. Control and supervisory equipment is integrated with the programme input equipment, both for ease of installation and because they are closely associated in function.

In common with IBA television stations, a philosophy of duplicating all active equipment in the programme path has been adopted, coupled with an automatic control system which is designed to ensure that no single failure should take a station off the air. Thus limiters, compressors, power supplies, etc., are duplicated and failures are sensed by programme break detectors suitably placed in the transmission chain. Supervisory logic produces the appropriate change-over commands to reserve equipment.

An important feature of the ILR operation is that the Programme Contractors themselves have the direct responsibility for monitoring the quality and continuity of the transmissions, rather than the IBA, although of course IBA maintenance teams are available on call to repair faults or restore transmission after a fault report. This situation is partly brought about by the fact that only a minority of ILR transmitters can be received at existing IBA control centres, and further, that the number of such centres may be reduced in the foreseeable future.

No remote controls of ILR stations have been considered necessary, with the one exception of stereo/mono selection at VHF stations for reasons given later.

To give some early warning that a non-catastrophic fault has occurred, an over-air signalling system has been developed which can raise an alarm at the Programme Contractor's premises, which can then be reported to the IBA if necessary.

Programme Paths

It is helpful to have a clear picture in mind of the structure of the programme paths so that the configuration of the programme input equipment can be appreciated. Fig.1 shows the most common arrangement in a typical contractor's area, involving a VHF and an MF station.

A matched pair of lines from the studio to the VHF station is rented from the Post Office, together with a single line from the studio to the MF station. The use of two separate lines to carry the A and B components of the stereo signal avoids the difficulty and cost of

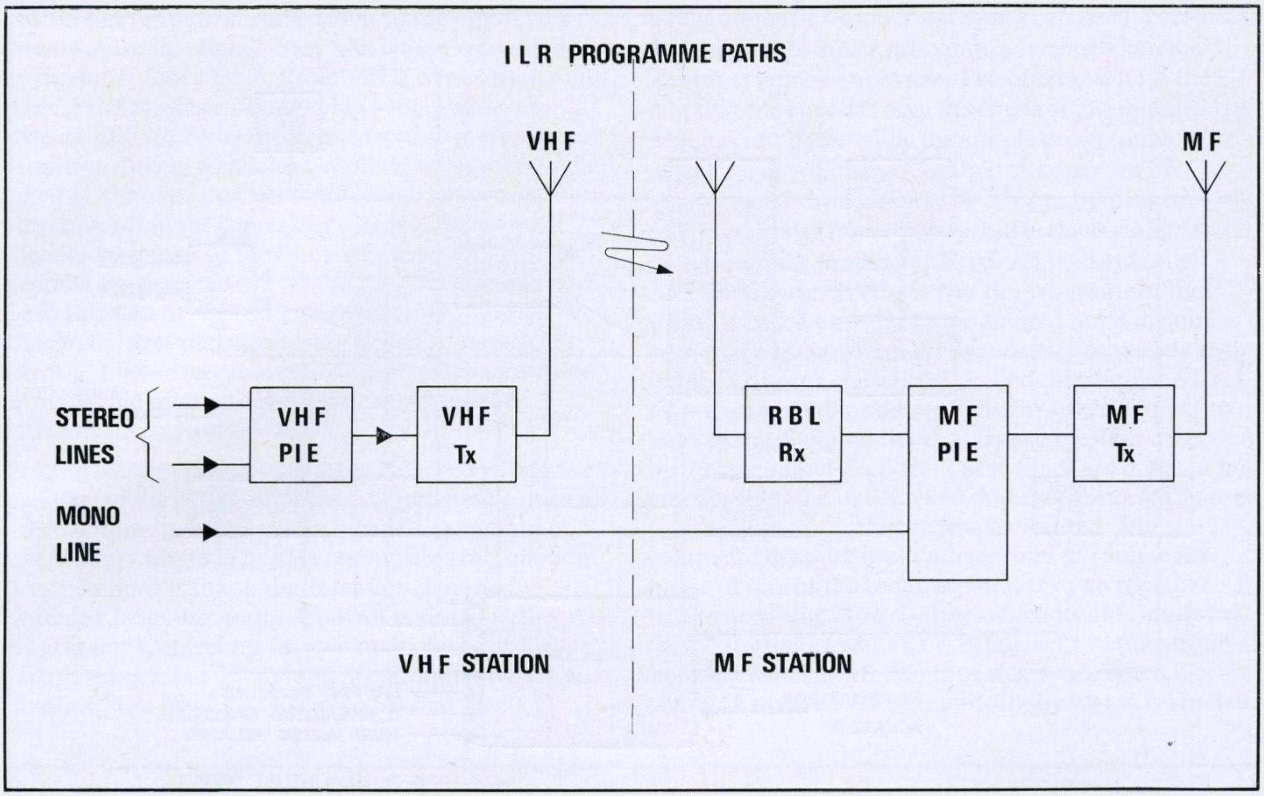


Fig.1. ILR programme paths, showing the relationship of the VHF and MF transmitters in a Programme Contractor's area.

equalising a single circuit to carry encoded stereo. If a failure to mono can be defined as a non-catastrophic fault, this arrangement can be said to provide a measure of duplication. The stereo coder in the system is therefore located at the transmitting station, rather than at the studio, but is not in fact duplicated.

The sum of the A and B components of the stereo signal has to be presented to the associated MF transmitter, so the components are summed at the studio and fed to the single MF line. The alternative path to the MF station is provided by off-air reception of the VHF station using a receiver without a stereo decoder. The wanted sum signal therefore appears by virtue of the stereo/mono compatibility of the Zenith-G.E. stereo system.[1]

The Programme Contractors are equipped with VHF and MF receiving systems and, being in the primary service area, are in a position to receive good signals for quality monitoring purposes. It is a requirement that an indication of the presence or absence of stereo pilot-tone is easily visible to the studio operator.[2]

Certain areas have slightly different programme paths; for example one area has to be covered by a second VHF station relaying the first. In this case VHF receivers feed low-power VHF transmitters, but the stereo signal is not decoded and re-coded for obvious reasons. However, the general case is the one which is described in most detail and illustrates the objectives of the system design.

Programme Input Equipment at VHF Stations

Fig.2 shows the general arrangement of the VHF programme input equipment.

The signals from each incoming line are fed to separate limiters, which have a limiting characteristic related to the frequency response corresponding to the 50 microsecond pre-emphasis used for VHF FM broadcasting in the UK. This is necessary to prevent peaks of programme at the higher audio frequencies from overdeviating the transmitters, with the attendant risk of excessive distortion.

The gain control circuits of the limiters are inter-connected. If the limiters were allowed to operate

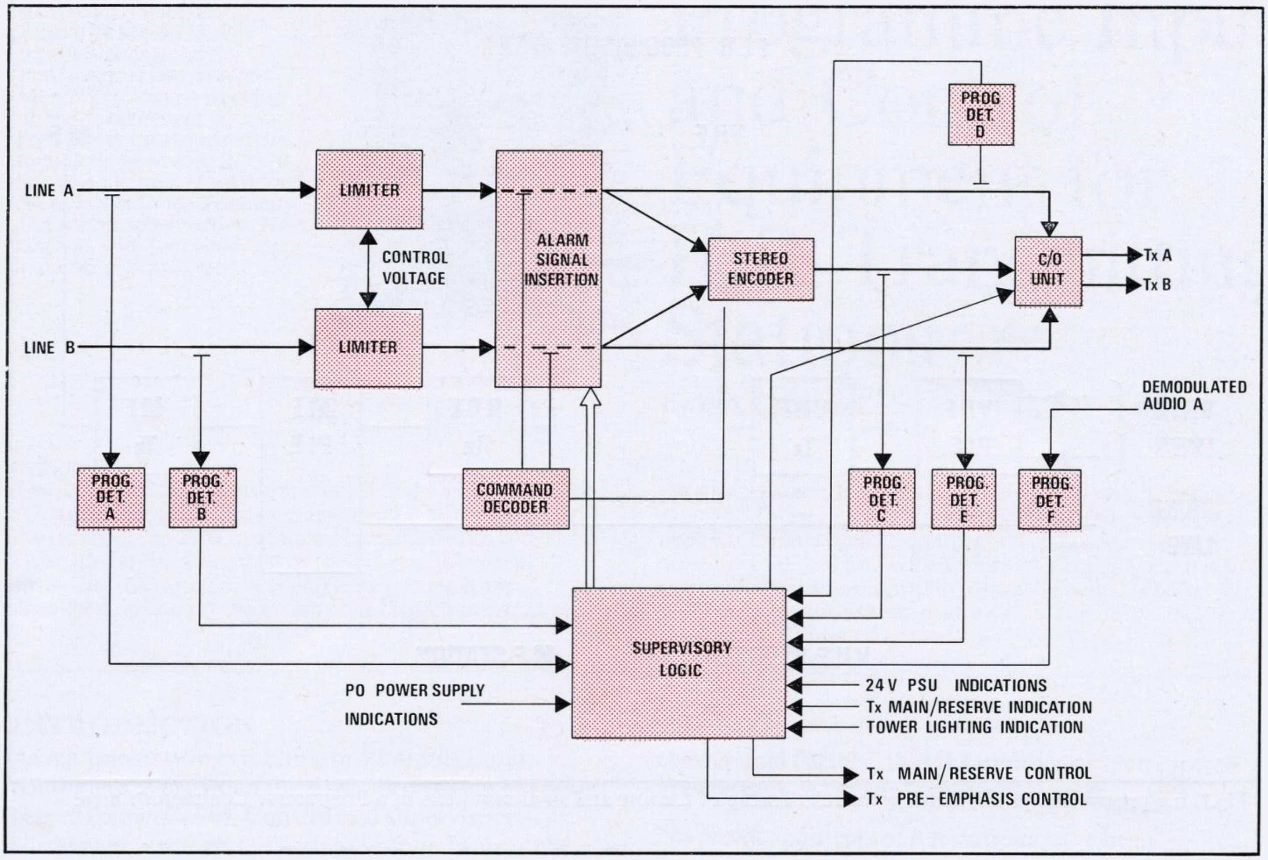


Fig.2. VHF programme input and control equipment, showing the signal path through the system and the positions of programme detectors in the chain which locate faults in the duplicated paths.

independently, it would seem most unlikely that their gains at any instant could ever be equal, due to circuit tolerances and the fact that the A and B components of a stereo signal can be quite different from time to time. If this were ignored, the stereo image would move about at random as the limiters operated, producing a spurious subjective effect.

The limiters are provided to forestall over-modulation if the sending levels or line losses differ from their correct values for some reason.

The two limited signals are fed to the inputs of the single stereo encoder which generates the standard multiplex signal for transmission. A block diagram of the stereo encoder is shown in Fig.3, where it will be noticed that there is provision for Subsidiary Channel Authorisation (SCA) inputs, should this service be added later. The sum of the A and B signals occupies the audio spectrum from 30Hz to 15kHz, there is an unmodulated pilot tone at 19kHz to synchronise receiver decoders, and the difference-signal amplitude modulates the suppressed 38kHz sub-carrier, making up the complete stereo multiplexed signal.

The encoder is a relatively expensive item of programme input equipment and has not been duplicated at this stage for several reasons. Automatic detection of a failure in coding with a view to automatic encoder change-over was considered, but it was felt that the detection circuitry would have been as complicated as that of the encoders themselves, and therefore equally fault prone. As it is, the encoder reliability is expected to be significantly higher than that of other parts of the station, such as the high-power output stages of the transmitters. Thus straightforward detection of continuity of the audio path through the chain, with automatic failure to mono after a fault, is felt to be adequate.

The limiter outputs are also taken to the inputs of a three-way audio change-over unit which is controlled by the supervisory logic. Programme detectors A and B sense the presence of incoming programme, an absence of both being interpreted as a shut-down condition during which no switching action should be taken at the station. Detector C senses the encoder output, leading the supervisory logic to by-pass the encoder by means of the three-way changeover unit if inputs are detected but no output. Detectors D and E are satisfied by the limiter outputs and also lead the logic to by-pass the encoder if one input seems to be missing. Low-level passages could produce unwanted reversions to mono, so the logic outputs of the detectors are suitably delayed.

Normal stereo/mono switching is achieved within the encoder, so the programme input equipment can be in either of three modes – stereo, intentional mono, or reversionary mono. The sole remote control function at VHF stations is the stereo/intentional mono switching from the studio. Control is vested in the Programme Contractor for two main reasons. He may wish to transmit in mono long programmes which have not been produced in stereo, so that listeners with automatic decoder switching can benefit from the 20dB signal-to-noise ratio improvement when the Zenith system is not in use. The other reason is the fact that the encoder may develop a slight impairment which is not detected by the simple programme detector but which the Contractor notices in his quality monitoring area. He is able to by-pass the offending coder immediately, but is then confined to mono until the fault is repaired. An in-band tone command system is used over the programme lines, which is based on a phase-modulated burst of sub-carrier at 14kHz. When change-over is required the burst, of approximately 0·5 second duration at a level of −24dBm and modulated with a 'select mono', or 'select stereo' digital word, is transmitted for detection by the command decoder. These tones are inserted in antiphase on the two lines so that they cancel in a mono receiver and are therefore less noticeable. The command decoder is of course wired to reverse the phase of one of the tones and add the two together before decoding. The control switch itself is mounted on the studio operator's desk, adjacent to the off-air stereo indication. He can thus clearly see when his control has taken effect, a philosophy which is applied

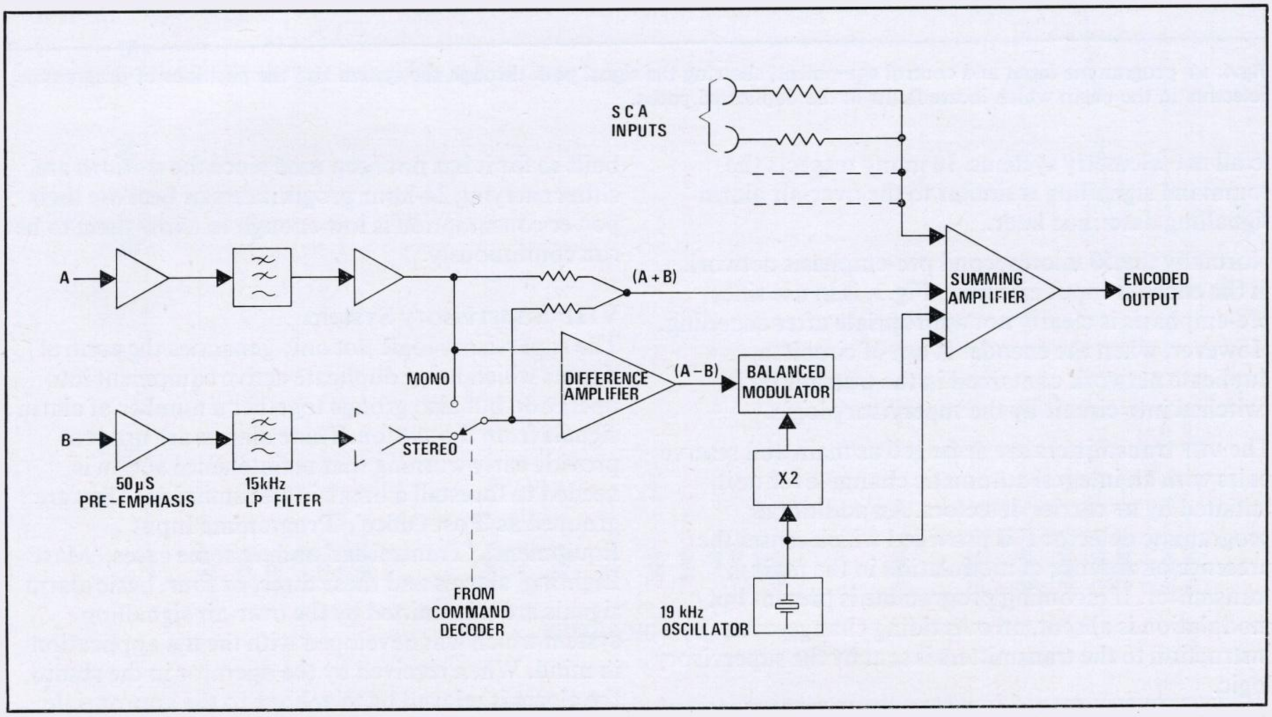


Fig.3. Stereo encoder, showing how the mono/stereo switching is normally achieved within the encoder and the provision of subsidiary channel authorisation (SCA) inputs for possible future use.

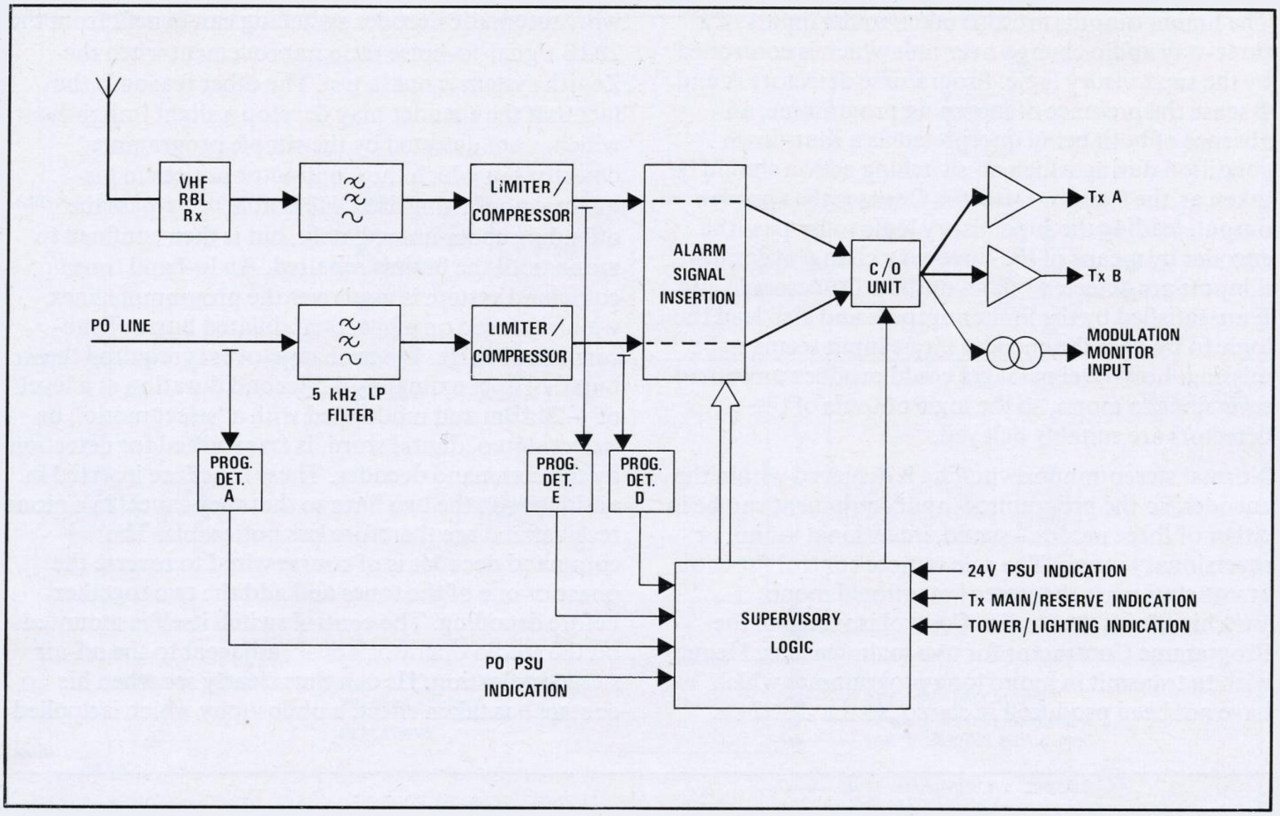


Fig.4. MF programme input and control equipment, showing the signal path through the system and the positions of programme detectors in the chain which locate faults in the duplicated paths.

to all IBA telemetry systems. In many respects the command signalling is similar to the over-air alarm signalling described later.

Normally the 50 microsecond pre-emphasis network in the encoder input circuitry, Fig.3, is in use since pre-emphasis is clearly not appropriate after encoding. However, when the encoder is out of circuit, a duplicate network contained in the transmitter is switched into circuit by the supervisory logic.

The VHF transmitters are arranged as main and reserve pairs with an integral automatic change-over unit initiated by RF carrier detectors. An additional programme detector F is provided which senses the presence or absence of modulation in the main transmitter. If incoming programme is present but modulation is absent, an overriding change-over instruction to the transmitters is sent by the supervisory logic.

A station start/stop signal is available, based on the detection of incoming programme. At ILR stations built so far it has not been used since the stations are either carrying 24-hour programmes or because their power consumption is low enough to allow them to be run continuously.

VHF Supervisory System

The supervisory logic not only generates the control signals which bring duplicate active equipment into operation but also groups together a number of alarm signals from the station. These alarms are used to provide early warning that maintenance action is needed to forestall a break in transmission. They are grouped as 'Post Office', 'Programme Input Equipment', 'Transmitter' and, in some cases, 'Mast Lighting' alarms and these three, or four, basic alarm signals are transmitted by the over-air signalling system which was developed with the ILR application in mind. When received by the operator in the studio, the alarm is relayed by telephone to the appropriate IBA maintenance team manager who must then decide who should attend to a particular fault.

Earlier supervisory systems used at television stations[3] have operated over the Post Office public switched telephone network, using automatic dialling and answering units, with their relatively expensive line isolation and protection measures. It was realised that, by exploiting the over-air path from the transmitting station to the studio to send early warning messages, much of the cost and complexity of telephone dialling units could be avoided. The fact that the 'data' transmission path vanishes when the station comes off the air is immaterial since early warning is not applicable and the Contractor himself is soon aware that his programme is no longer being broadcast.

When an alarm signal enters the supervisory logic unit, a burst of 14kHz tone, suitably modulated according to which of the three, or four, basic categories it belongs, is added to the programme for approximately 0·5 second, and to prevent audio components, or their harmonics, from distorting the data, a notch filter, centred on 14kHz is switched into the programme path for the duration of this period. The alarm signal is transmitted at the relatively low-level of –34dBm before pre-emphasis so that in the normal way it is barely perceptible, and is repeated after 15 seconds by way of confirmation. In the particular case of a transmitter failure, because the change-over time is determined by valve heating, the supervisory signals are delayed by a little more than three minutes to allow the reserve transmitter to become fully operational.

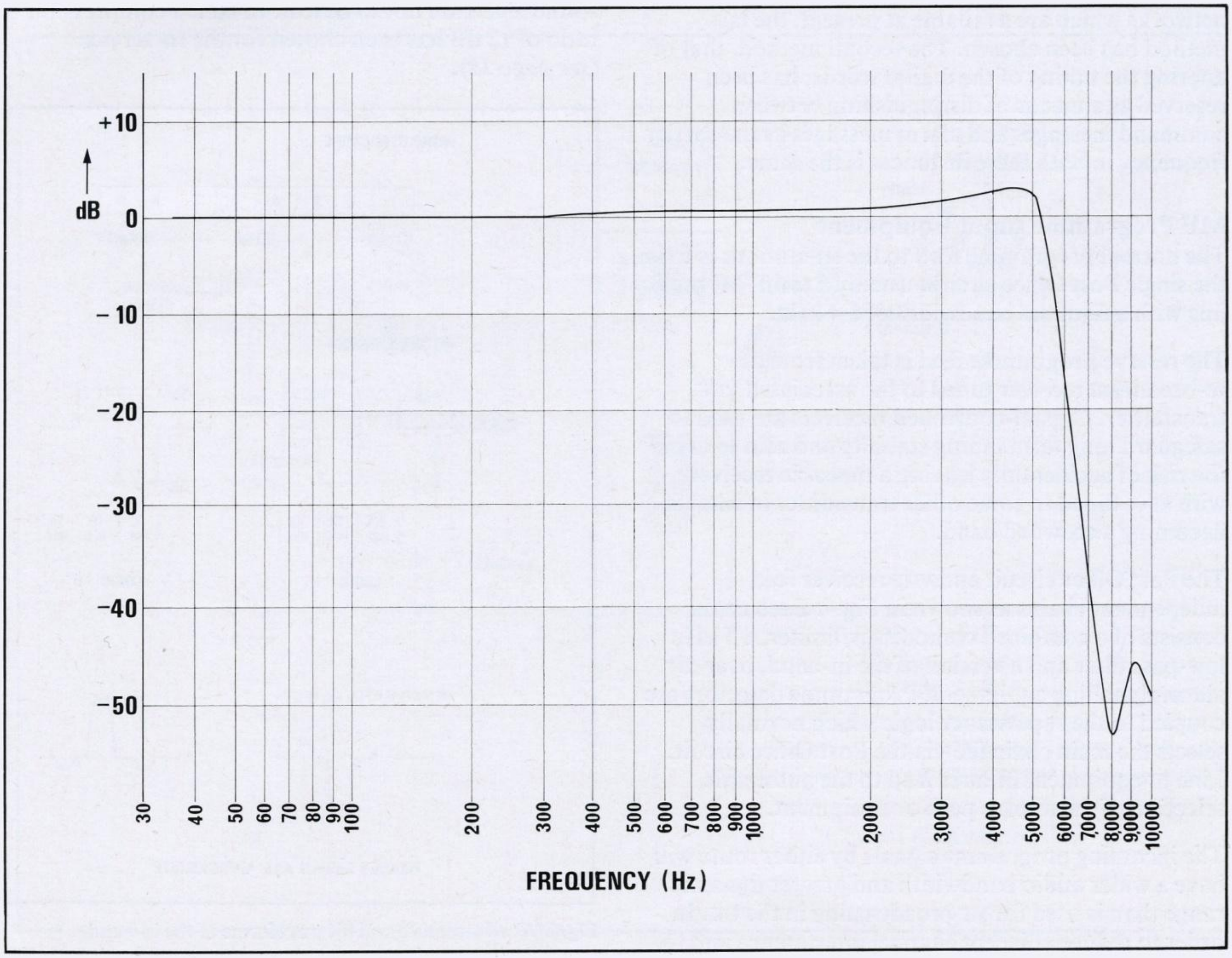


Fig.5. The curve shows the response of the AF band-limit filter used in the case of the MF service to restrict out-of-band radiation and to minimise the consequent audible degradation.

At the studio a 'dedicated' VHF receiver, without de-emphasis, detects the tone burst and attracts the operator's attention. When it has been determined whether the call-out has been initiated at the studio, perhaps unintentionally by feeding only one line of the stereo pair, or whether the fault lies in the Post Office circuit or at the transmitting station, the operator then contacts the IBA.

Where one VHF station re-broadcasts from another, it will also repeat the alarm messages, and some electronic means of distinguishing between the two possible sources of the message becomes necessary. A number of options are open. It would be possible to lengthen the digital word to include address bits, or to change the fundamental bit rate, or to use a different sub-carrier frequency. In the relatively simple networks which are available at present, the last method has been chosen. The second method, that of altering the timing of the digital words, has been reserved as a means of distinguishing between command messages and alarm messages as the carrier frequency in both these instances is the same.

MF Programme Input Equipment

The normal programme feed to the MF stations is from the single Post Office circuit, usually a tariff 'M' music line with a nominal bandwidth of 6·4 kHz.

The reserve programme feed is taken from a re-broadcast receiver tuned to the associated VHF transmitter. Crystal-controlled receivers are used to safeguard long term tuning stability and also to avoid the risk of accidentally leaving a tuneable receiver, with AFC, tuned to some other transmitter in what is becoming a crowded band.

The Post Office circuit and VHF receiver feed independent chains as shown in Fig.4. Each chain consists of a combined compressor/limiter, a 5 kHz low-pass filter and a version of the in-band, over-air alarm signalling equipment. Programme detectors are coupled to the supervisory logic which normally selects the main chain fed via the Post Office circuit. Line or equipment failures lead to the automatic selection of the reserve path or equipment.

The incoming programme signals by either route will have a wider audio bandwidth and greater dynamic range than is used for MF broadcasting in the UK. In order to reduce adjacent channel interference and to occupy no more than the allocated bandwidth, the programme is band-limited to approximately 5 kHz, using an active filter of IBA design. The response of the filter is shown in Fig.5. The slight lift in response before the main roll-off has been found to produce less audible degradation of quality than a maximally flat roll-off.

The limiter/compressors follow the filters for reasons discussed below. Limiting is required, as at the VHF stations, to protect against over-modulation. Compression is required to reduce the dynamic range of the programme signals to a suitable value for MF broadcasting. The studio output can be expected to have a maximum dynamic range of 40 dB, which is handled quite adequately by the VHF service. However, the much poorer signal-to-noise ratio of the MF service in the European environment makes it advisable to restrict the range by between 8 and 13 dB if the lower sound levels are not to be lost. In fact, a compression ratio of 12 dB has been chosen for the MF service (*see page 13*).

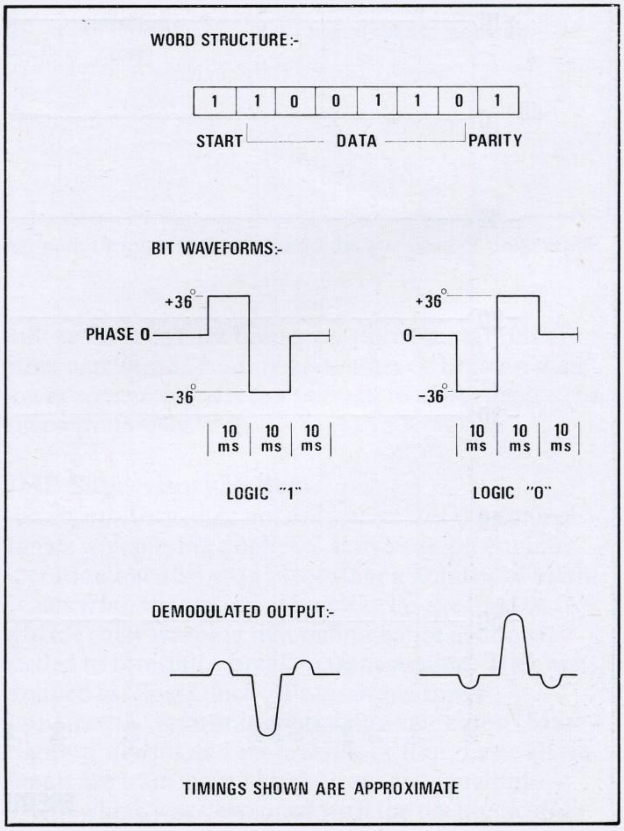


Fig.6. Word structure and bit waveforms of the in-band signalling system, showing the phase changes used to transmit the digital words and the demodulated waveform which has to be restored to logic signals.

The limiting process inherently introduces distortion and it might be thought that the low-pass filters should be placed after the limiters so that distortion products above 5 kHz would be attenuated. However, the distortion introduced by the type of limiter/compressors in use is negligible in comparison with the distortion allowed in other parts of the system. For example, at an input level of +20 dBm and an output level of +8 dBm, the typical distortion does not exceed 0·4%. The filters can therefore be placed ahead of the limiter/compressors so that audio frequency components beyond the restricted 5 kHz band cannot cause the compressors to operate pointlessly.

The programme chain is completed by audio distribution amplifiers, the number being determined by the transmitter configuration which may need two, three or four parallel inputs. The amplifiers also allow the levels to each transmitter to be set up individually.

The transmitter assembly includes an automatic change-over unit fed by a proprietary modulation monitor, which requires a reference audio input from the programme input equipment.

Any transmitter change-over or reversion to re-broadcast programme feed is signalled by an over-air signalling system which is almost identical with the VHF system. The difference is that a sub-carrier of 4·7 kHz is used, so as to be just within the MF audio pass band.

No remote controls are considered necessary for the MF stations. The supervisory logic uses the same circuit elements as the VHF version, and is designed to

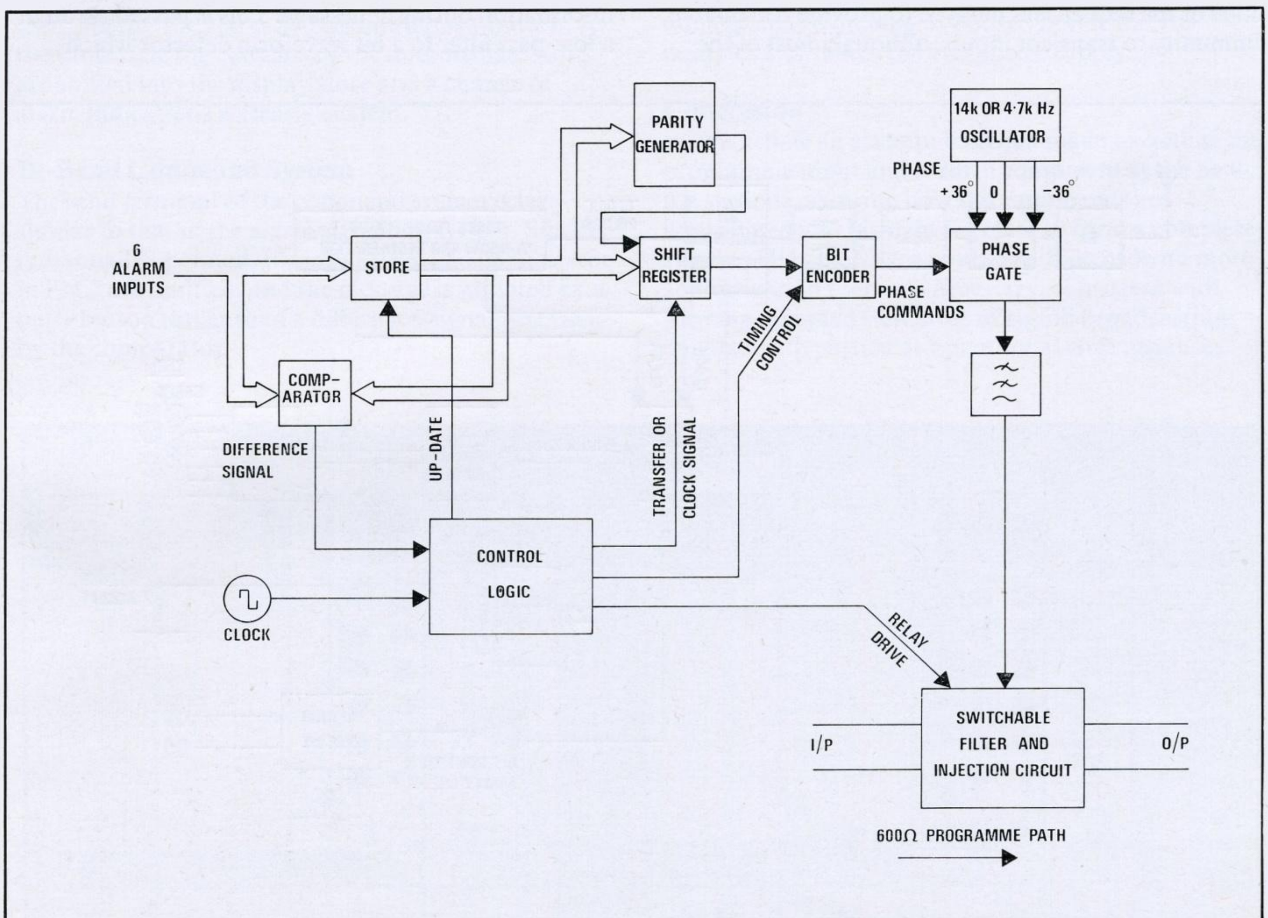


Fig.7. Alarm signalling system—send terminal. This diagram shows in more detail how a digital word is assembled from the incoming alarm information and superimposed as a bit waveform phase modulating the subcarrier of 14 or 4·7 kHz for the VHF and MF services respectively.

cater for either requirement by using a number of optional straps or links.

Over-air Signalling System

Up to six different alarm messages may be sent in the form of digital words, the structure of which is shown in Fig.6. An eight-bit word is used consisting of a start bit, 6 data bits and a final parity bit whose value depends upon the preceding data. The words are used to phase modulate the signalling sub-carrier using the bit waveforms shown. A deviation of $\pm 36°$ is applied and each bit occupies approximately 30 milliseconds altogether.

The block diagram of the send terminal, Fig.7, shows how the system is arranged. The six alarm inputs are presented to a store and comparator so that any change initiates the alarm signalling sequence. The start of the sequence is delayed to provide reasonable immunity to transient inputs, although most of the input buffering is performed in the associated supervisory logic which assembles the inputs. Once a change has been detected, the control logic inserts a notch filter at subcarrier frequency into the programme path and then injects undeviated sub-carrier for approximately 100 milliseconds. During this time the phase-locked loop decoder in the receive terminal locks onto sub-carrier. The message is then transferred serially from the shift register, before sub-carrier is cut and the notch switched out of circuit again. The whole sequence occupies rather less than 0·5 second and the sending level is low enough to be barely perceptible to the average listener.

The block diagram of the receive terminal is shown in Fig.8. The audio output of the pretuned VHF or MF receiver is applied to a phase-locked loop (PLL) the control voltage of which carries the wanted information during a message. This is passed through a low-pass filter to a bit waveform detector which

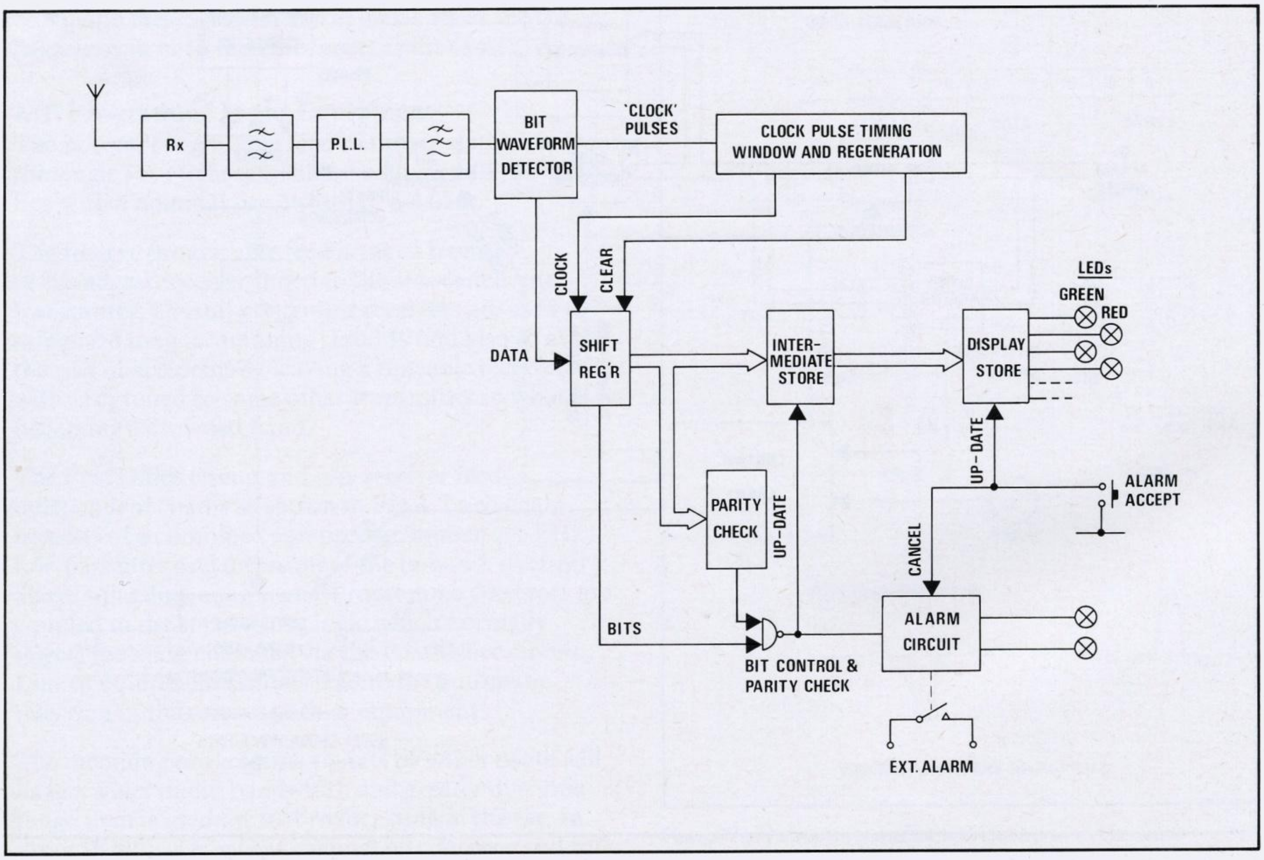


Fig.8. Alarm signalling system—receive terminal. This diagram shows in more detail how the phase modulated tone burst is first transformed into a bit waveform and then restored to the form of a digital word in a store for display.

reconstructs the bit stream from the effectively differentiated input. The stream of pulses which emerges can be regarded as a stream of clock pulses and it is therefore processed to ensure that the pulses are genuine and are not produced by programme components at sub-carrier frequency, or by interference, or noise. Unless the pulses are within 20% of the correct repetition rate, the shift register in which the data accumulates is cleared at regular intervals. For a message to be accepted the first bit must be a '1', the following 7 bits must satisfy the parity check and the clock rate must be within 20% of its correct value.

When a valid message has been accepted the alarm circuit is triggered and the intermediate store receives the contents of the shift register. The external alarm circuit will attract the operator's attention who can then 'accept' the alarm by pressing a push-button. At the same time the contents of the intermediate store are shifted into the display store and a change of alarm indications is clearly evident.

In-Band Command System

The send terminal of the command system is very similar to that of the alarm signalling system. Since it is manually operated, the input store and comparator in Fig.7 are omitted, and the message is initiated by a push-button rather than a difference-signal generated by the comparator.

Similarly the receive terminal is as Fig.8 but an audio rather than an RF input is required and the display section of red and green light emitting diodes (LEDs) is replaced by latched relays to be used as control outputs. In this case a message is acted upon as soon as parity is satisfied. As already mentioned, the command clock is set to a different frequency from that in the alarm system to obtain a different bit rate and thus interaction between the two signalling systems is avoided.

Fig.9 shows the complete assembly which is supplied to a studio. The VHF receiver and 14 kHz display decoder correspond to the block diagram of Fig.8. Similarly the MF receiver and 4·7 kHz display decoder correspond to Fig.8 for the MF service. The command transmitter, which accepts a simple push-button signal from the operator's control desk for mono/stereo switching, is housed beside the VHF modules and shares the VHF power supply.

Conclusion

In this article an attempt has been made to outline the programme input and control equipment at the new ILR stations, showing how the equipments are interrelated and brought together to form a complete system. The objective was always to provide no more sophistication than was necessary, consistent with meeting accepted standards of sound broadcasting coupled with particular operational circumstances.

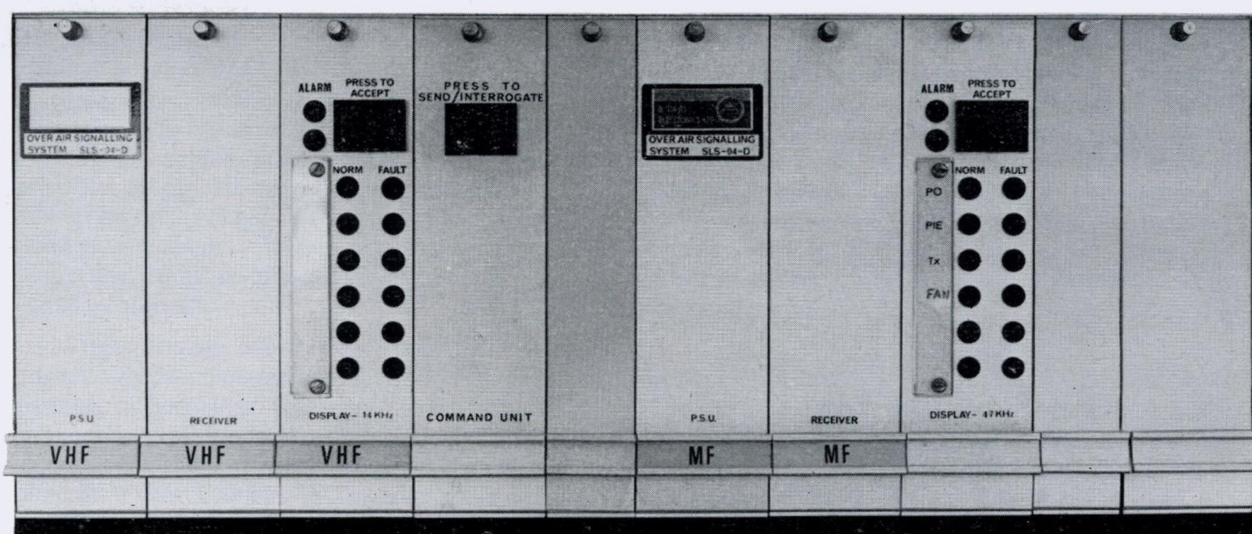


Fig.9. Supervisory and command equipment provided at the studio, including dedicated VHF and MF receivers, display decoders and the coded tone command unit.

No doubt the system will be developed over the next few years as a result of operational experience or new developments. For example, a need has already been felt for the studios to be able to trigger an alarm signal to confirm a puzzling message or obtain reassurance that the system, which should only have reason to call-out relatively infrequently, is still operating. At VHF stations this is conveniently achieved by using a spare control channel of the stereo/mono command system but at MF stations a method using an interrupted low-level tone is being investigated.

Developments such as sub-carrier quadraphony, SCA broadcasting on sub-carriers in the 60-80 kHz region, noise processing or more advanced automatic monitoring methods could well influence the design of future stations.

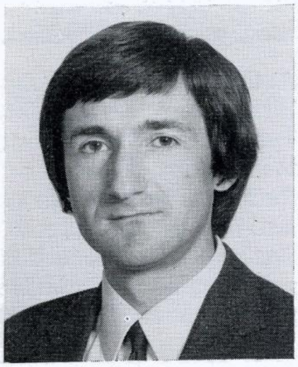
References

1. 'Pilot Tone Stereo System'—CCIR Recommendation 450, Vol. 5, Part 1, New Delhi 1970.

2. 'Code of Practice for ILR Studio Performance' Section 5, Broadcast System Operational Requirements, *IBA Technical Review* **2**

3. 'Control Systems for Television Transmitting Stations', *IBA Technical Review* **4.**

TED FORD, prior to joining the IBA in 1972, was with the European Space Research Organisation where he was responsible for feasibility and development studies on UHF and microwave aerials for space craft and the placing of applied research contracts with European industry. As a member of the Masts and Aerials Section, within the Station Design and Construction Department, his responsibilities since joining the IBA have been principally centred on the design and engineering of the Authority's network of MF transmitting stations for Independent Local Radio in collaboration with the IBA's North American consultants, and the placing and progressing of the contracts for these systems with UK aerial suppliers.



Directional MF Aerial Arrays for the Independent Local Radio Service

by E T Ford

Synopsis
Of the proposed sixty MF transmitting stations for the new Independent Local Radio service in the UK, about half a dozen which serve the main conurbations require the use of highly directional aerials. The reason for this is to conserve the valuable UK frequency allocations by employing the same channel several times over, giving different programme services in each target area. Highly directional patterns are needed to direct deep nulls towards the cities served by co-channel stations.

This article presents a brief history of the planning undertaken by the IBA for the installation and commissioning of these aerials. To illustrate a typical case, the design, construction and measured performance of the four-mast array at Manchester are described.

INTRODUCTION

Of the sixty MF transmitting stations proposed for the new Independent Local Radio Service in the UK, about half a dozen which serve the main conurbations require the use of highly directional aerials. This is to conserve the valuable UK frequency allocations by employing the same channel several times over, giving different programme services in each of the target areas. Highly directional patterns are needed, not to obtain high gain in the main beam but to direct deep nulls towards the cities served by co-channel stations.

In 1971 the Authority made extensive studies in the use of highly directional MF aerials. There was little practical experience in Europe, so that as well as making our own theoretical studies and discussing the problems with aerial designers, we obtained advice from the United States and Canada. In North America well over 2000 directional aerials were in successful operation so there was a considerable background of experience in their design, installation and long term performance. Some of the aerials were quite complex and achieved remarkable patterns. For example, at station KSOO a 5-mast endfire array had a measured rearward radiation characteristic which was 30 dB below the main beam signal over a 180° arc. At WNLC, a 6-mast endfire array achieved a 30 dB null over a 90° arc broadside to the beam. At KLIF, a 12-mast array was used to generate two narrow beams of different gains at right-angles to each other, while 30 dB nulls were aimed in various specified directions. These were exceptional cases, but they demonstrated what can be achieved[1].

Station Planning

The land area required to install a directional aerial is very large, especially at the lower frequencies. Taking into account the costs of the land, the radiating structures and the aerial tuning networks, it was considered that directional aerials were more appropriate to the part of the band above 1 MHz, and arrays using not more than four elements were preferred.

Aerial patterns from various arrangements of two, three and four elements were available from the literature and these were studied by the Authority's service planning engineers. From an analysis of MF propagation within the UK, together with agreement on standards for field strengths and protection ratios, evolved the pattern specifications which were found to require aerials generally with three or four elements to provide nulls down to −26 dB relative to the main beam.

From the results of the studies in North America the following conclusions were drawn concerning the IBA requirements:

— endfire arrays were the best arrangement to guarantee meeting the skywave rejection limits in the directions of the co-channel stations;
— null depths of −26 dB would be achievable over arcs of up to 20° in azimuth, with adequate stability;
— the IBA's aerial requirements were regarded as quite normal in North America, where far tighter specifications were often imposed and met;
— efficient and stable MF performance depends as much upon sound structural and civil engineering practice as upon good electrical design.

While aerial planning was taking place, negotiations were proceeding for obtaining suitable sites. The requirements of each site were manifold; for example, the bearing of the site relative to the city centre was an important restraint, since co-channel protection nulls could only be directed at angles of at least 70° away from the direction of the main beam. Obviously the site had to be of sufficient area to allow installation, and its shape and orientation had to be roughly correct. The distance from the city centre had to be within certain limits, typically four to ten miles, otherwise radiation patterns or transmitter powers would become unreasonable.

At such proximity to cities, difficulties were often experienced in finding suitably large available areas of open ground.

Aerial Design

The Authority decided to employ a North American consultant to provide an electrical design for each directional aerial to satisfy a specification and templet produced by the Authority. Designs were commissioned for aerials at the major conurbations of Birmingham, Glasgow, Manchester, Sheffield, Tyneside (Tyne/Wear), Liverpool and London. Contractors from the UK were then invited to tender for the supply, installation and setting-to-work of the aerial equipment specified.

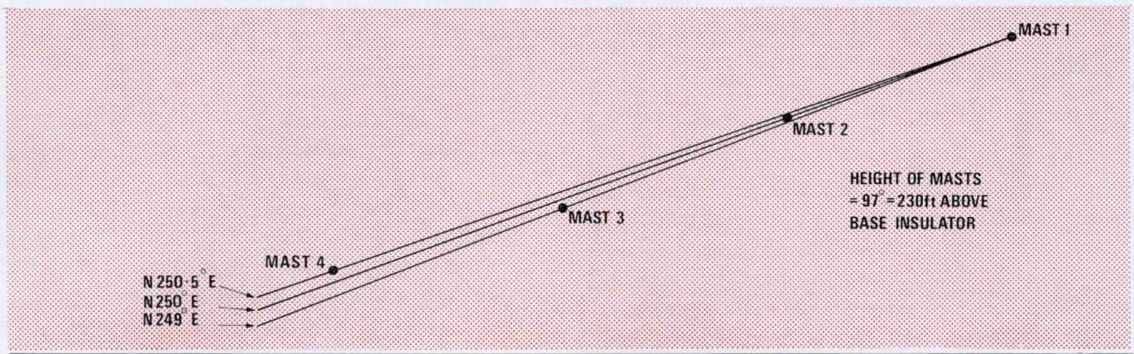
At the time of writing (July 1974) the aerials for Birmingham, Glasgow, Manchester, Sheffield and Tyne/Wear have been installed and set to work, and the first three of these have been in programme service for several months. The London aerial, currently being installed, will be of special interest as it will be the first highly-directional dual-frequency array, providing London with two programme services from a common set of four masts on one site.

In order to illustrate the nature of directional arrays and the performance that can be achieved, the Manchester station is selected as an example of a fairly stringent radiation-pattern specification requiring four radiators.

Electrical Design of Manchester Array

The ILR medium wave service for Greater Manchester is transmitted from an array of four guyed mast-radiators, installed and commissioned at Ashton-under-Lyne in November 1973. The steel lattice masts, which themselves carry the RF currents, are each 234 feet high with a triangular cross section of 2 ft face width, and are arranged as an endfire array aimed at 250° ETN to cover central Manchester about 5 miles to the west. Electrically, the masts are just over one quarter-wavelength high and are spaced apart by about a quarter-wavelength at the operating frequency of 1151 kHz. The earthmat consists of a quarter-wavelength radial system comprising 120 copper wires per mast. Figure 1 is a sketch of the mast layout and shows that the masts are not quite in line and their spacings are not quite equal. These small deviations from a symmetrical endfire arrangement give rise to asymmetry in the null regions of the radiation pattern. In the south, towards Birmingham, a deep null is created whereas to the north the null is filled in to provide programme service at close range.

The aerial was designed around a set of mast currents, derived from computer analysis, to achieve the theoretical radiation patterns shown in Fig.2. The figure shows the groundwave and skywave patterns superimposed upon the IBA specification templet, and is generally self explanatory. The radiated power of directional arrays is expressed in decibels relative to 1 kW (dBkW) as radiated from a hypothetical short vertical monopole radiating over a perfectly conducting flat ground plane. 0 dBkW is equivalent to an unattenuated field of 186 mV/m at 1 mile range.



MAST NUMBERS	SPACING FROM MAST 1	
	FEET	ELECTRICAL DEGREES
2	201·8	85°
3	427·3	180°
4	640·9	270°

Fig.1. The transmitting aerial for the local radio MF service at Manchester consists of four mast-radiators forming a vertically-polarised endfire array. The masts are 234 feet high and extend over a baseline of 640 feet. A slight 'dog-leg' in the line of masts produces an asymmetric radiation pattern necessary to meet the coverage and the co-channel protection requirements. The array is installed at Ashton-under-Lyne and directs its main radiation lobe towards Manchester on a bearing of 250° ETN.

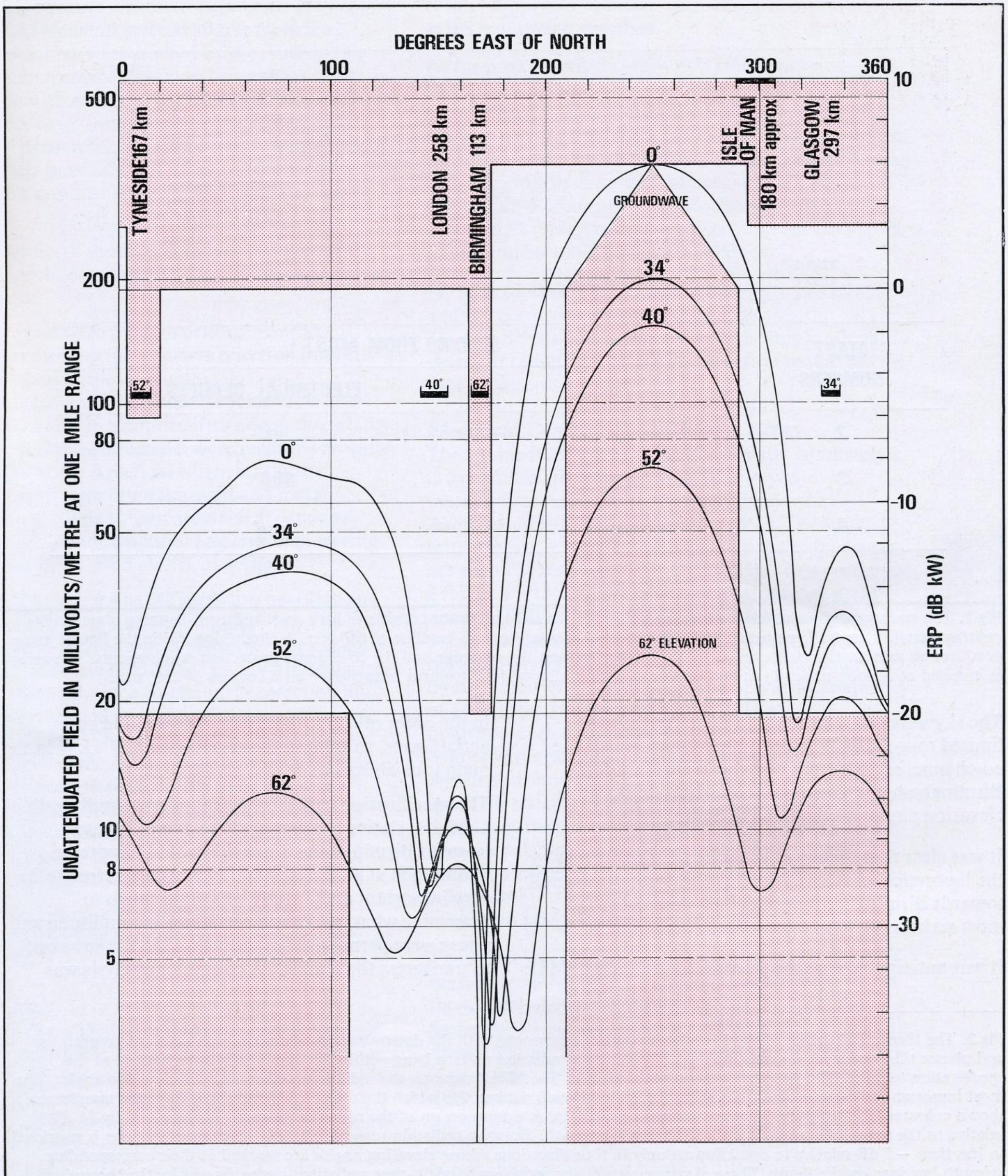
The skywave ERP, expressed in these terms, was limited to -5 dBkW in four directions towards the co-channel service areas of Tyne/Wear, London, Birmingham and Glasgow at appropriate skywave elevation angles marked on the figure.

It was clear that the skywave limits were easily met by the theoretical patterns. Meeting the groundwave null towards Birmingham seemed likely to present the most serious problem in practice.

It was anticipated that the transmitter power would be in the order of 700 to 1000 watts, depending upon aerial losses, to achieve the specified ERP of 4 kW in the main lobe direction.

The specification called for a groundwave null depth of -26 dB relative to the main lobe over a 10° arc towards Birmingham. Since this would have to be maintained at all times, stability was considered to be very important and a study was undertaken to determine what maximum variations in amplitude and phase were permissible in the mast currents so as not to transgress the templet. A computer analysis was

Fig.2. The theoretical design of the Manchester aerial commenced with the determination of a set of mast-current amplitudes and phases that under ideal conditions would produce a radiation pattern lying within the upper and lower bounds of the specification templet. The figure shows computer plots of five 'slices' through the radiation pattern at fixed elevation angles. The most important of these is the 0° elevation (i.e. groundwave) pattern, for which the upper and lower bounds of the templet are shown coloured on the figure. The most severe requirement is a suppression of the radiation towards Birmingham by 26 dB relative to the main lobe which is only 75° away in azimuth. Skywave radiation towards the four co-channel stations is restricted to less than -5 dB relative to one kilowatt only in four directions whose elevation angles are marked at their corresponding azimuth bearings on the figure. These skywave restrictions, applying to night-time radiation, are easily met by the theoretical pattern.


DEGREES EAST OF NORTH
0
100
200
300
360
500
200
100
80
50
20
10
8
5
10
0
-10
-20
-30
UNATTENUATED FIELD IN MILLIVOLTS/METRE AT ONE MILE RANGE
ERP (dB kW)
TYNESIDE167 km
LONDON 258 km
BIRMINGHAM 113 km
ISLE OF MAN 180 km approx
GLASGOW 297 km
GROUNDWAVE
62° ELEVATION
0°
34°
40°
52°
62°

performed, involving the perturbation of the theoretical currents by uncorrelated random errors in amplitude and phase, and the study showed that variations with peak values in the order of $\pm 0{\cdot}3$ dB and $\pm 3°$ were typical of those which should not be exceeded. It was already known that some directional aerials operating in the USA showed seasonal variations of about 7 dB (peak-to-peak) in those parts of the pattern which were, on average, about 26 dB below the main lobe. The information was derived from measurements made at stations WGH (3 masts), WANN (2 masts) and KLIF (12 masts)[1]. Our theoretical studies had shown that such a variation ($+3$ dB to -4 dB) could occur if the maximum random errors in the mast currents were $\pm 0{\cdot}3$ dB and $\pm 3°$. It is interesting to note that this agreed closely with the measured current variations at the stations, the maximum variations over 12 months being typically $\pm 0{\cdot}4$ dB and $\pm 2°$.

The theoretical studies were carried out on the Experimental and Development Department's computer and graphical plotter. In fact, this computer was used to make a number of general studies into MF aerial performance, including the prediction of mutual and operating impedances in an array of mast radiators, involving the numerical evaluation of complex integrals. Another study was the prediction of near-field intensities close to multi-mast arrays, with results displayed in a contour-map presentation. An example of this is shown in Fig.3.

Aerial Installation

Unlike television, local radio requires the erection of radiating structures within a few miles of city centres, usually in urban areas, and the Authority's policy is that in such circumstances the visual obtrusion upon the skyline should be minimised. Consequently, for the first directional stations the chosen structures were guyed masts rather than self-supporting towers, with mast heights limited to about one quarter-wavelength and emphasis placed upon slim cross-section and clean silhouette.

In urban areas generally, the only suitable sites for aerial installations covering 5 to 10 acres are arable land. Here again, to avoid sterilising large areas, grazing rights are given back to site owners and tenants on all sites where grass is predominant. The installation of the earthmat wires at a depth of 12 in. by moleplough minimises soil disturbance and loss of grass on such sites.

At Ashton-under-Lyne the site was originally a market garden and despite the fact that the aerial earthmat covered 8 acres almost the whole of this surface was made available again to the tenants, for the cultivation of shallow rooted crops, by installing the earthwires relatively deeply at 24 in. to 30 in. Aerial efficiency nevertheless proved excellent, owing to the damp highly-conducting soil.

The mast radiators are fed by buried coaxial cables from the transmitter building about 200 feet away. This building, measuring about 25 feet x 14 feet, houses a 1 kW transmitter and an aerial network cabinet containing a four-way power divider and four phase-trimming circuits in series with the feeder cables. The cables are of different lengths to provide the coarse phase differences between the masts and, since these lengths do not coincide with the physical lengths to the masts, excess cable is coiled and buried adjacent to the transmitter building.

In the aerial network cabinet, power division is made by tapping off at four points from the inductor of a tank circuit. The coarse taps feed into four variable vernier inductors with handwheel tuning on the cabinet front panel.

The power divider is matched to the transmitter by a T-network. The outputs from the vernier inductors are fed through phase-trimmers consisting of symmetrical T-networks with ganged variable inductors connected to front panel handwheels.

Impedance matching of the masts to the feeder cables was accomplished with T-networks mounted in small cabins at the mast bases. The circuits were designed to match the predicted operating impedances of the masts, and were provided with a wide range of control to cater for inevitable differences between predicted and actual impedances when the final radiation pattern was set up.

Monitoring of the mast currents can be performed in two ways. First, the currents could be read from the thermocouple ammeters inserted in series at the mast bases. The current readings are absolute values but the amplitude cannot be determined to a high degree of accuracy.

The second method indicates phase as well as amplitude, but in this case all readings are essentially relative, there being no absolute calibration in amperes. On one leg of each mast column an unshielded loop samples a very small proportion of the leg current and sends this back to the transmitter

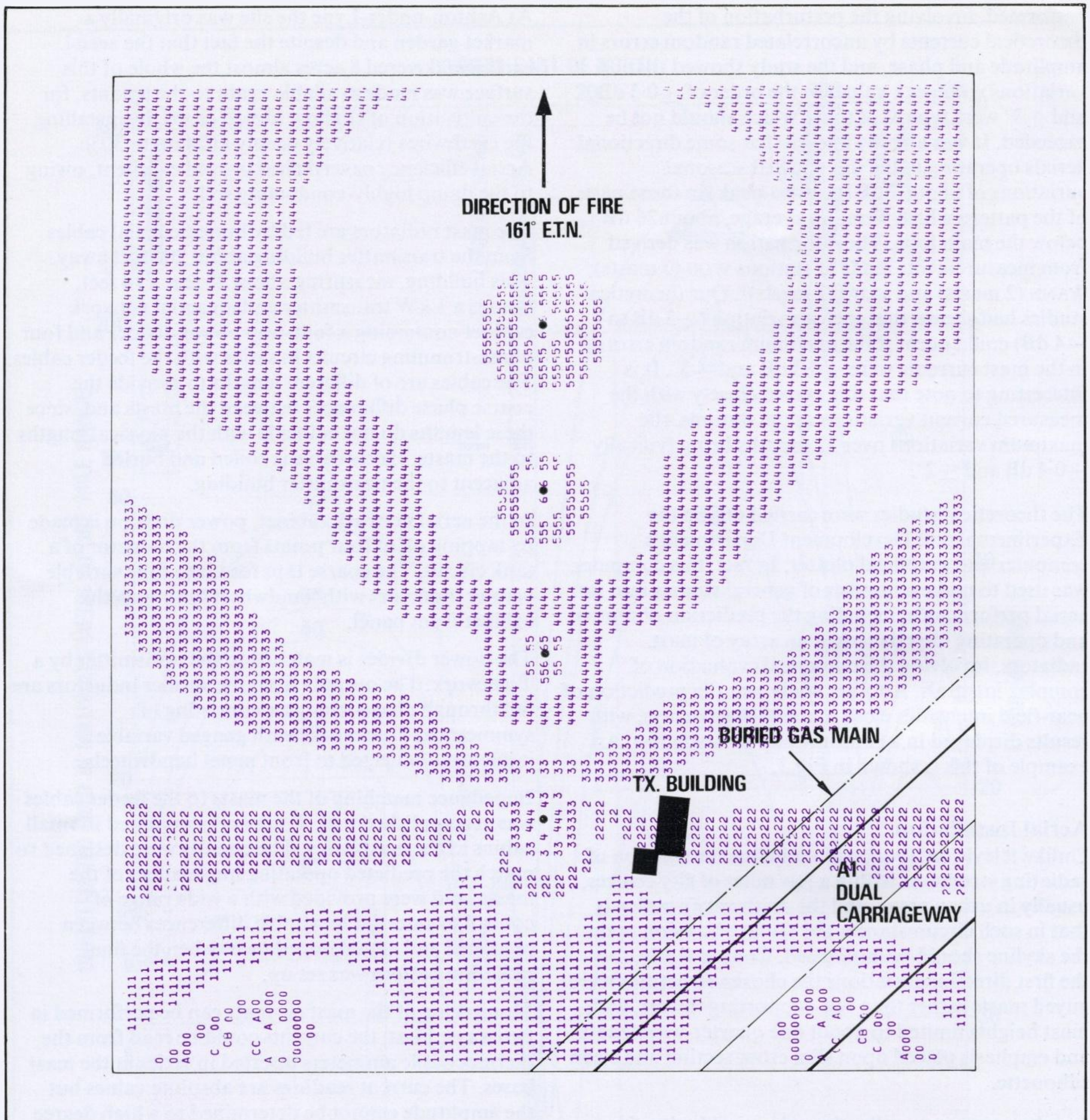
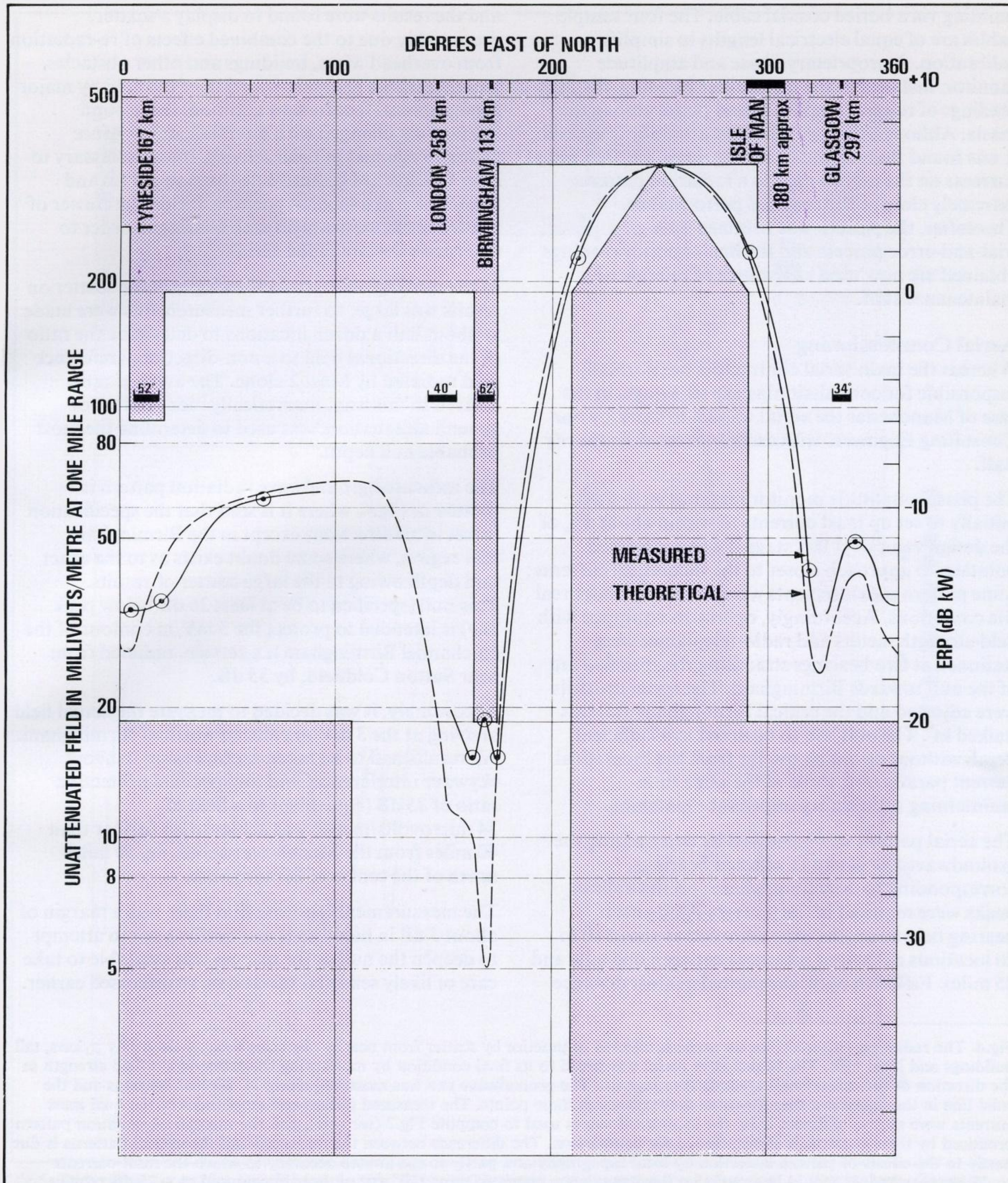


Fig.3. Computer-produced contour map presentations have been used to provide insight into the nature of electromagnetic fields in close proximity to MF aerial arrays. For the two London services, relatively high transmitter powers will be used to feed two programmes into a common set of four masts at a site near Borehamwood. One task was to predict the field strengths at the transmitter building and adjacent public highway, and determine the soil currents induced at a cathodically-protected gas main buried nearby. The figure shows one example of a field map plotted in plan around the four masts for the 'London General' service at a frequency of 1546 kHz and a transmitter power of approximately 25 kW. The masts are spaced 200 feet apart. The theoretical values of the vertical electric field component at and near ground level, where the horizontal component is zero, are plotted as numerals N, where: Total Field Intensity (at ground level) = (N × 10 − 20) dB relative to 1 volt/meter.


DEGREES EAST OF NORTH
0
100
200
300
360
+10
0
-10
-20
-30
ERP (dB kW)
500
200
100
80
50
20
10
8
5
UNATTENUATED FIELD IN MILLIVOLTS/METRE AT ONE MILE RANGE
TYNESIDE 167 km
LONDON 258 km
BIRMINGHAM 113 km
ISLE OF MAN
180 km approx
GLASGOW 297 km
52°
40°
62°
34°
MEASURED
THEORETICAL

building via a buried coaxial cable. The four sample cables are of equal electrical lengths to simplify calibration. A proprietary phase and amplitude monitor, installed at the transmitter building, displays readings of relative amplitude and phase among the masts. Although the measurement accuracy is limited it was found that the initial setting up of the theoretical currents on the monitor led to a radiation pattern extremely close to the required performance. Thereafter, the pattern was trimmed by a trial-and-error process and the final monitor readings obtained are now used as a source of reference by maintenance staff.

Aerial Commissioning

Whereas the main aerial contractors are normally responsible for commissioning the MF arrays, in the case of Manchester the aerial was set to work by our Consulting Engineers with assistance from Authority staff.

The phase/amplitude monitor readings were used initially to set up mast currents to within about 5% of the design values. At this stage it was considered pointless to approach closer to the theoretical currents; some pattern measurements were necessary under real site conditions. Accordingly, operators equipped with field-strength meters and radio-telephones were stationed at two bearings straddling the specified arc of the null towards Birmingham. The aerial controls were adjusted and the critical Birmingham null was 'talked in'. The null had to be tuned to a sufficient depth without deviating too far from the theoretical current parameters, while at the same time maintaining satisfactory impedance matching.

The aerial pattern was measured by determining the groundwave ERP along 11 selected bearings, corresponding to directions where specific nulls or peaks were required in the pattern. Along each bearing field strengths were recorded at about 10 to 20 locations at various distances between one mile and 25 miles. Field strength was plotted against distance and the results were found to display a scatter, presumably due to the combined effects of re-radiation from overhead wires, buildings and other obstacles, together with a general distortion of the field by major topographical features. In addition, the ground attenuation changed with direction and distance owing to changes in conductivity. It was necessary to refer to standard ground-attentuation curves and locate these at a median position within the cluster of plotted measurements on each bearing in order to determine the ERP of the aerial.

In the null region towards Birmingham the scatter on results was large, so further measurements were made at about half a dozen locations to determine the ratio of the directional field to a non-directional reference field radiated by Mast 2 alone. The average ratio derived in this way, theoretically independent of ground attenuation, was used to determine the most probable null depth.

The measured groundwave radiation pattern is plotted in Fig.4, where it is seen that the specification is met in all directions except in the Birmingham null region, where some doubt exists as to the exact null depth owing to the large scatter of results. This null (specified to be at least 26 dB below peak ERP) is intended to protect the 3 mV/m contour of the co-channel Birmingham ILR service, radiated from near Sutton Coldfield, by 35 dB.

Accordingly, it was decided to measure the actual field arriving at the 3 mV/m contour north of Birmingham. All results had to be taken around noon to avoid skywave interference, and the specified protection ratio of 35 dB (equivalent to a field of 54 microvolts/metre) was achieved no further than 40 miles from the Manchester aerial, i.e. 30 miles north of the centre of Birmingham.

The measurements showed that there was a margin of about 3 dB in hand, so it was decided not to attempt to deepen the null as the margin was available to take care of likely seasonal variations, as discussed earlier.

Fig.4. The radiation pattern of an MF aerial is affected in practice by scatter from nearby obstacles such as electricity pylons, tall buildings and local hills. The Manchester aerial was tuned to its final condition by monitoring the groundwave field strength in the direction of the critical null towards Birmingham. The groundwave ERP was measured along 11 selected bearings and the solid line in the figure is a smooth curve drawn through these points. The measured phases and amplitudes of the final mast currents were slightly different from the theoretical values used to compute Fig.2 (*see text*), and the theoretical radiation pattern produced by these currents is shown dotted for comparison. The difference between the measured and theoretical patterns is due partly to the effects of pattern distortion by local topography and partly to the limited accuracy to which the mast currents could be measured. It should be noted that the groundwave suppression at 170° ETN, although measured at −26 dB relative to the main lobe, proved in practice to have adequate margin for protecting the Birmingham co-channel service area, so further pattern adjustment was not necessary.

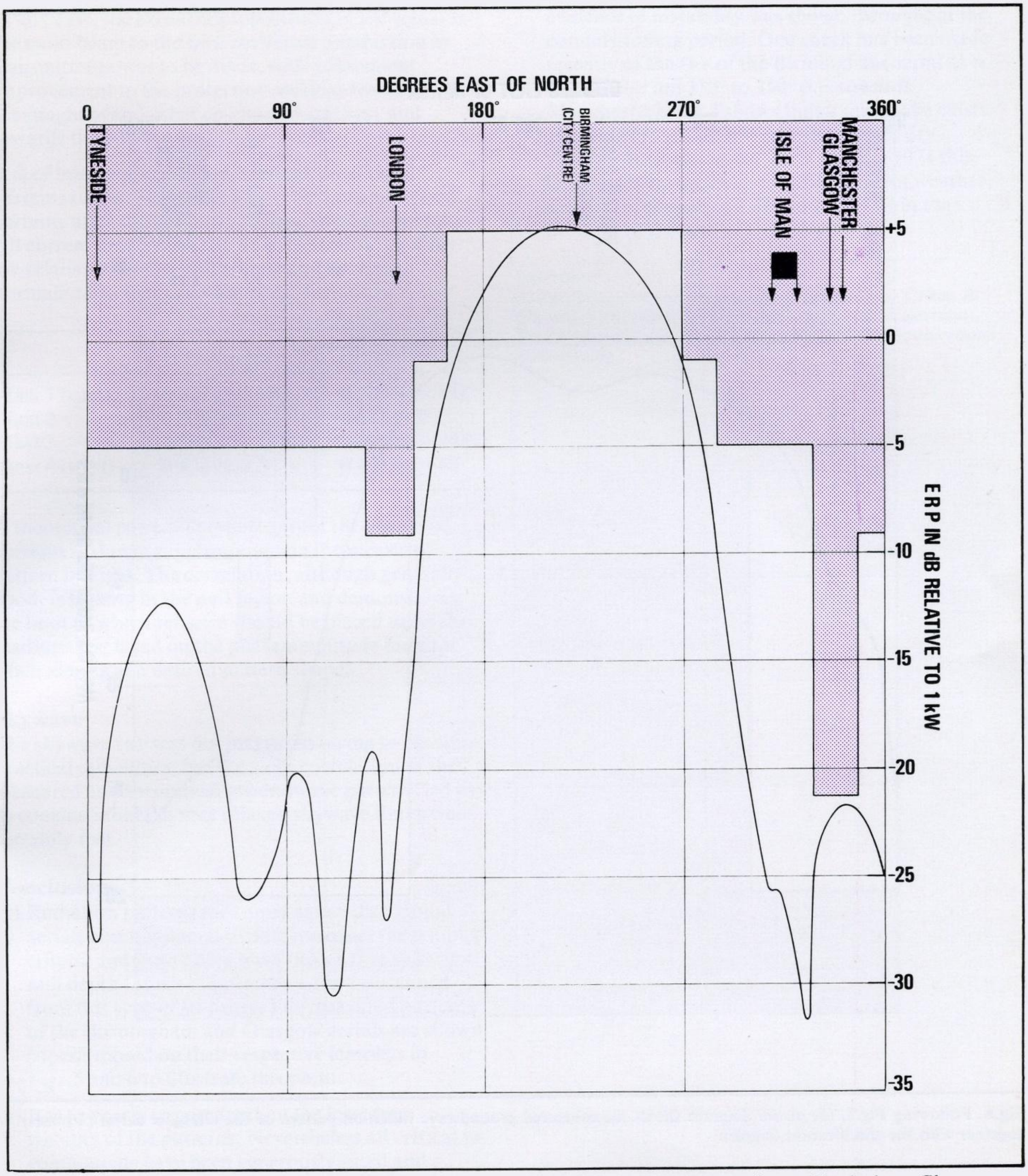


Fig.5. Directional MF endfire aerials have, to date, been installed and commissioned for ILR services at Birmingham, Glasgow, Manchester, Tyneside (Tyne/Wear) and Sheffield. The first four stations, all co-channel, are now on-air. The measured groundwave radiation pattern of the Birmingham aerial (4 masts) is shown here, superimposed on its specification templet to illustrate that sufficient null depth for ILR requirements can be attained from this type of MF array.

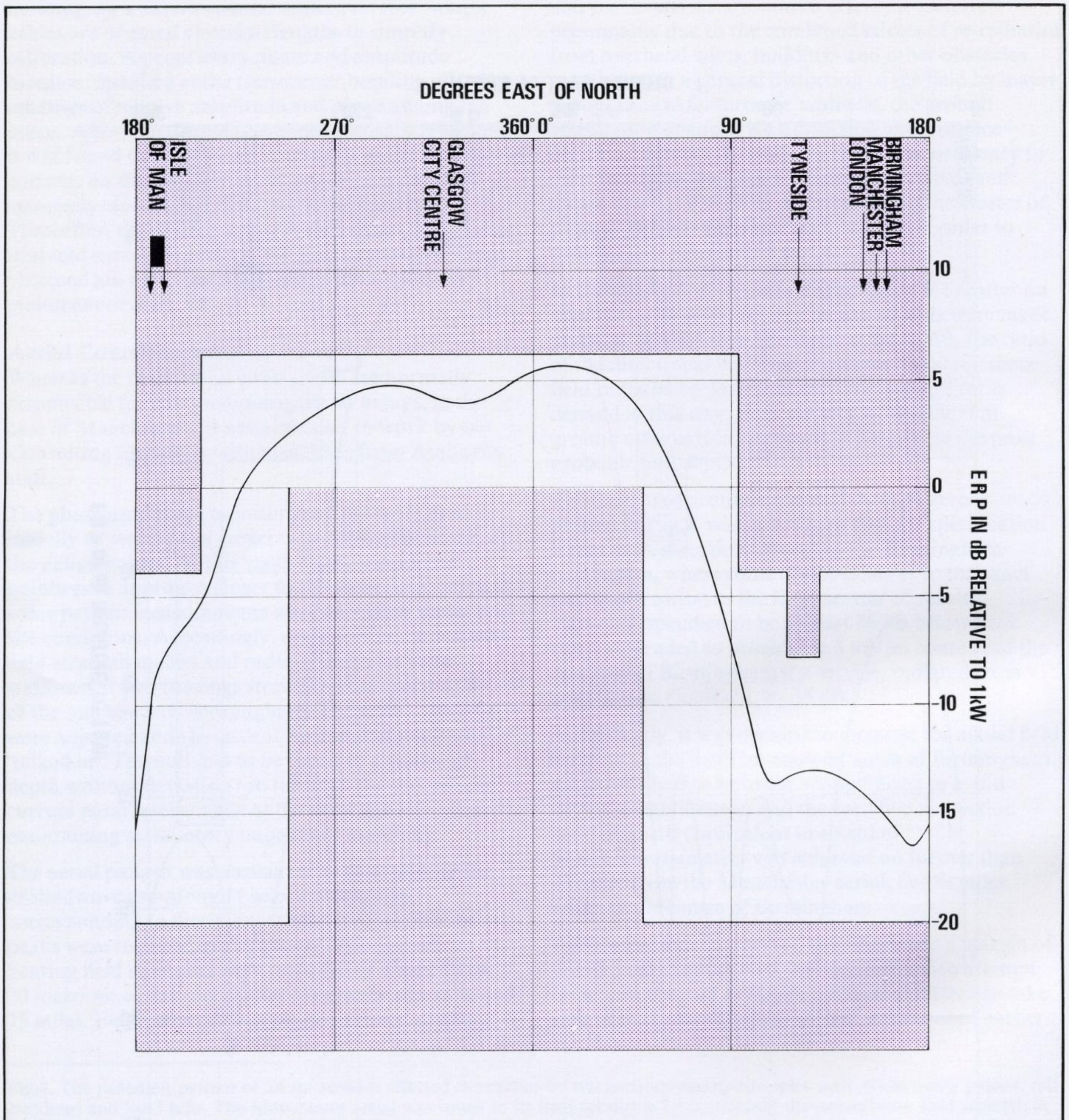


Fig.6. Following Fig.5, the above diagram shows the measured groundwave radiation pattern of the Glasgow aerial (3 masts) together with the specification templet.

In any case, the excellent propagation of the signal in the main beam to the west permitted a reduction in transmitter power to be made, with consequent improvement to the protection margins towards Birmingham and other co-channel stations, and towards the Isle of Man.

It is of interest to compare the theoretical mast currents (used to compute Fig.2) with the measured currents after the radiation pattern had been set up. All current amplitudes shown in the following table are relative values, not absolute, and have been normalised to the current in Mast 3.

	Theoretical	*Measured*
Mast 1 (east)	0·377 at +143°	0·405 at +143°
Mast 2	0·804 at 0°	0·815 at 0°
Mast 3	1·000 at −149°	1·000 at −145°
Mast 4 (west)	0·494 at +54°	0·475 at +60°

A theoretical pattern computed from the *measured* currents is shown superimposed on the measured pattern in Fig.4. The correlation, although generally good, is lacking in the null region and demonstrates the limit to which reliance should be placed upon the readings displayed on the phase/amplitude monitor, when aiming at a desired pattern shape.

Skywave

The skywave ERP was not measured owing to obvious practical difficulties, but the close correlation of the measured and theoretical groundwave patterns led us to conclude that the very relaxed skywave limits were certainly met.

Conclusions

(i) Radiation patterns measured at five directional aerials commissioned to date have met the templet criteria and in so doing have shown that sufficient null depth for ILR requirements can be attained from this type of MF array. The measured patterns of the Birmingham and Glasgow aerials are shown superimposed on their respective templets in Figs.5 and 6 to illustrate this point.

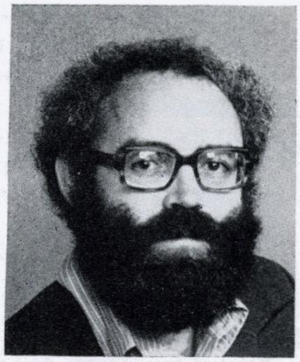
(ii) It is too early to comment on the long term stability of the patterns. Nevertheless all critical RF components have been generously rated and particular care was taken in the installation of the earthmat. It is anticipated that this will considerably assist in the stability of the system and no evidence of instability was shown throughout the commissioning period. One check has been made recently of the ERP of the Birmingham aerial over the angular arc 330° to 350° (i.e. towards Manchester). Fig.4 shows that a small lobe exists at a level of −22 dBkW as measured in dry weather during October 1973. In June 1974 this lobe was measured at −24 dBkW in wet weather, a seasonal change of 2 dB which is within the limits anticipated.

References

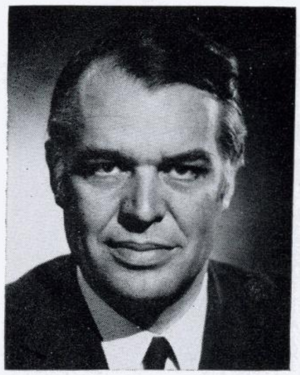
1. Proof-of-performance documents prepared by Cohen & Dippell, PC (Consulting Engineers – Radio and Television), Washington DC, USA; on file at the Federal Communications Commission.

Design and Operation of a Studio Centre for Independent Local Radio

by G O'Reilly and D Whittle



GERRY O'REILLY, Chief Engineer of Capital Radio Ltd., started his career by completing an electronics engineering apprenticeship with the Ministry of Aviation and an HNC Course at the Thames Polytechnic. He subsequently worked as a group leader with ITT Semiconductors before moving into the broadcasting field with the British Forces Broadcasting Service and, later, the Canadian Broadcasting Corporation. Prior to joining Capital Radio he held the position of Senior Engineer at the EVR Partnership's video unit.



DAVID WHITTLE, MA, C ENG, FIEE, FIERE, after graduating from Queen's College, Cambridge, joined Marconi Company Ltd. as a graduate apprentice. Having been involved in studio planning of a number of television studios, he spent eight years as Chief Engineer of the independent television studios in Birmingham and later held a similar post in Southern Television. For the past seven years, he has been Director of David Whittle Associates, Technical Consultants, who were responsible for the technical and systems planning for many independent television colour studio centres and were also responsible for the technical planning of Capital Radio Ltd., the Independent Local Radio contractor providing general programmes in the London area.

Synopsis
This article describes the planning, design and operation of the studio centre of Capital Radio, the London general Independent Local Radio station. It details the criteria used in the selection of a site, the design of the appropriate studios and the methods of operation. It concludes with a summary of the lessons learned from the initial period of operation and suggests areas of interest for future investigation.

INTRODUCTION

The IBA granted Capital Radio Limited the franchise for the Independent Local Radio general station on 7th February 1973. The management of Capital Radio, in conjunction with the IBA, decided that the opening date for transmission in stereo VHF, and MF, should be in October 1974. This meant that there were eight months in which to find a suitable site for the studios, design a suitable layout, order, obtain, install and test equipment, recruit the necessary staff and prepare for the first day of transmission. This short time scale imposed severe limitations on the planning phase and, because many of the senior staff had yet to be appointed, discussions with them regarding their particular requirements were impossible. The design was, in fact, based on the estimates of requirements outlined in the company's application to the IBA.

Site Selection

It would have been highly desirable to find a vacant site in Central London and build a purpose-made studio centre from the ground. Obviously, the time scale precluded any such approach and a search was instigated for the lease of a suitable building. The criteria used for the search were:

1. Space requirements for studios.
2. Space requirements for offices.
3. Structural suitability for conversion vis-a-vis loading and acoustic isolation.
4. Reasonable accessibility for vehicles and the public.
5. A reasonably imposing frontage.
6. Satisfactory leasing contract conditions.
7. Reasonably short distance from Post Office switching centre and availability of telephone, music and OB circuits.

A list of functions was drawn up with possible minimum and maximum areas required. Fig.1 shows these requirements for technical areas together with the actual areas eventually allocated. A similar exercise was undertaken for office areas giving a minimum total of 8,000 and a maximum of 10,000 square feet. In the event 12,000 square feet were used exclusive of plant rooms, reception and circulation.

The site finally chosen was the first floor and part of the ground floor of the Euston Tower block, Euston Road, and the first and ground floor areas available were 21,000 and 3,500 square feet respectively. Additional space was made available in the basement for vehicle parking and accommodation of stand-by generating plant. Fig.3 shows plans which were drawn up by the appointed architects using the area table as a guide and a scheme was evolved allowing some 3,000 square feet available for future expansion.

	Area in Square Feet Estimated Requirements			
	Minimum	Maximum	Mean	Actual
Studio 1	100	300	200	147
Studio 1 Control	100	150	125	120
Master Control	250	400	325	350
Studio 2	100	300	200	88
Studio 3	400	600	500	314
Studio 3 Control	150	250	200	179
Studio 4	400	600	500	570
Studio 4 Control	150	250	200	225
Telephone & OB Control	80	150	115	154
Editing Rooms	500	500	500	490
Listening Room	150	250	200	117
Technical Workshop	250	400	325	624
Technical Stores	250	500	375	235
Total Excluding Circulation	2,880	4,650	3,765	3,461

Fig.1. This shows the planned upper and lower limits for the technical areas and compares them with the actual sizes as finally built.

Fig.2. Some of the technical facilities available in Studio 4 control room are shown in this photograph. Studio 4 is primarily used for music programmes.

A master control room was situated in the centre of the technical complex with visual communication to surrounding studios and their associated control rooms. In order to maintain flexibility in the use of studios and control rooms, all were acoustically designed as if they were to be general purpose studios. Nevertheless, it was envisaged that each studio would tend to have a prime function and acoustic isolation for these functions was as far as possible designed into each area appropriately.

Studio 4 (570 sq. ft.) was intended primarily for music productions, i.e. pop groups, small orchestras, etc., with the possibility of a small studio audience. It was likely to have very high sound levels generated within, and the structure was, therefore, appropriately designed. As with each of the technical areas, a separate reinforced concrete slab was floated on a resilient mat off the structural floor and the internal walls and ceiling built off it. Between Studio 4 and the rest of the technical complex an additional wall was built between the structure floor and ceiling to provide additional isolation. Studio 4 control room (225 sq. ft.) was built adjacent to the studio, in a similar fashion, and was also additionally acoustically separated from the other technical areas by a wall carried directly on the structural floor. A double-glazed viewing window was provided between Studio 4 control and Studio 4, and also, triple-glazed windows between master control and Studio 4 and between Studio 3 control and Studio 4.

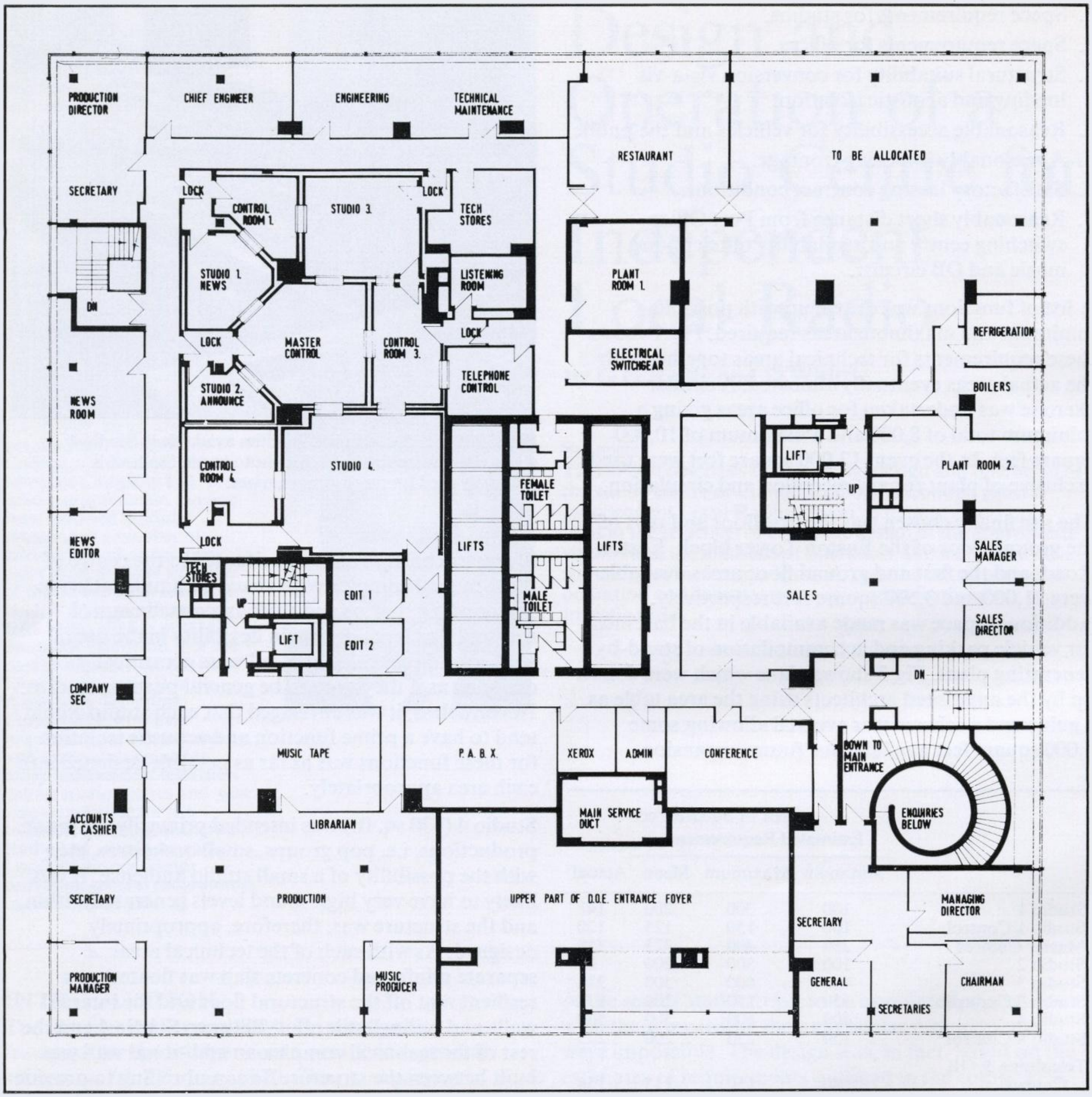


Fig.3. The first floor plan of Capital Radio Ltd. The figure shows that the studio complex is situated in the centre and is surrounded by the necessary office and production areas. This design, by the Ware Macgregor Partnership, took advantage of the additional structural strength in the centre and allowed additional acoustic isolation from the exterior for the studios by way of the circulation corridors and the perimeter offices.

Studio 3 (314 sq. ft.) was built primarily for talks and drama production and was constructed in a similar manner to the other technical areas as an isolated 'box within a box', the outer side bounding on the perimeter corridor of the technical area via a cavity and structure-carried wall. Double-glazed viewing windows were fitted between Studio 1 control and Studio 3, master control and Studio 3, and Studio 3

control and Studio 3. Studio 3 control room (179 sq. ft.) was particularly constrained in position and shape by the large structural columns carrying the tower block. A double-glazed window to Studio 3 gave a somewhat limited view, but similar windows to master control and the telephone control room were able to be satisfactorily positioned.

Fig.4. The operational position in Studio 3 control room. This has been engineered to serve as a stand-by master control room, but it is being used here in its production capacity.

Fig.5. The 'on-air' presenter is shown here working in Studio 2. This Studio is a self-operational disc-jockey area with facilities for interviewees and news inserts.

Studio 2 (88 sq. ft.) was designed as an Announcer's or 'disc-jockey' studio operating in conjunction with master control. It is almost triangular in plan and has a double-glazed window to master control.

Studio 1 (147 sq. ft.), a larger, almost triangular room, was intended for use as a news or small talks-studio but in practice is used mainly for the production of 'commercials'. It has been provided with viewing windows into master control and its own control room. This latter control room is 120 sq. ft. in area and triangular in shape, and it is also fitted with a viewing window into Studio 3.

The number of access points to areas requiring acoustic isolation was kept to a minimum and where possible sound isolation lobbies were shared. Air-conditioning and cable trunking was arranged, in most instances, to enter studios above the false ceiling of the sound isolation lobbies where acoustic attenuators for the air conditioning were generally accommodated. Although the designed acoustic isolation was achieved, there was no margin in hand due to limitations in the extra load which the existing structure could carry, and it was found that in certain conditions of high sound levels, in one area unacceptable breakthrough was occurring. Work was subsequently put in hand to examine the possibility of somewhat increasing the mass of the inner ceilings of studios and control rooms to increase the acoustic attenuation.

The acoustic treatment of studios and control rooms was designed to meet the IBA Code of Practice and was carried out by means of wall-mounted acoustic

Fig.6. A view of some of the technical facilities provided in Studio 1 Control. Above the 10-channel stereo mixer is an electronic music synthesiser. This control area is used for the production of commercials and promotions.

absorbers and ceiling-mounted expanded metal trays containing, as appropriate, absorbent or reflectant materials. Because of the particularly stringent fire regulations for the type of building, all materials used had to be non-inflammable. All the wall-mounted absorbers were constructed from steel sheet and filled with mineral wool as necessary for different parts of the frequency spectrum. All areas conformed with the IBA Code of Practice which specifies only the maximum permitted reverberation times and allows limited bass rise. However, it was found in practice that considerable advantages could be obtained by using reverberation times well below the maximum permissible limits, particularly in studios used for producing stereophonic dramas and pop music.

Technical Facilities

In the system design of the studio centre one of the important criteria was the ability to maintain an uninterrupted operational service for 24 hours a day. It was also necessary to provide stereophonic capability from the outset. All Post Office cables were routed to a room on the first floor, allocated for all line terminal equipment, telephone PABX equipment, house monitoring amplifier and distribution equipment, and 'phone-in' contribution equipment. All such equipment is unattended.

In master control, cables are run beneath a modular computer type floor covering most of the area, and rack mounted equipment and patch panels are mounted behind the operational control desk on

Fig.7. The operational position of the Master Control Room, showing the control desk and replay equipment. Here the operator can be seen looking into one of the adjacent studios whilst carrying out a pre-fade check.

either side of the window to Studio 3 control room. A purpose-built audio mixer was installed centrally so that the operator has a good view through the windows into Studios 1 and 2. A monitoring loudspeaker fitted above each of these windows, together with the operator's position, form the corners of an equilateral triangle the sides of which are 2 metres in length. The area, being acoustically treated to the same standards as a small studio, could be used by a presenter or disc-jockey in the 'self-drive' mode with a live microphone above the desk. Normally, however, the presenter is expected to operate a small sub-mixer in Studio 2.

Two disc-reproducers and two reel-to-reel tape recorders are mounted in the wings of the master control desk together with a triple-stack cartridge replay unit. All studio outputs and incoming lines are fed via patch panels and a solid-state switching matrix. Four microphone channels are provided for use with the master control desk, each fitted with pan-pots and simple compressors. It was expected that loudspeaker monitoring would normally be carried out in stereo using signals received from a VHF off-air receiver mounted in the racks, but frequent checks were also expected to be made on the MF mono off-air signal.

Both the VHF transmitter at Croydon and the MF transmitter, temporarily installed at Lots Road in Fulham (later to be sited in North London), were required to be unattended so this constant monitoring is essential and, as described elsewhere in this volume of *IBA Technical Review*, special rack-equipment was installed by the IBA to give transmitter fault alarms and indications of status. The alarms are repeated by indicator lights on the desk. In addition, a pilot-tone sensor in the VHF off-air receiver is arranged to illuminate one of two lamps on the desk to show the operational status of the stereo coding equipment at the transmitter.

Initially, it was thought that considerable advantage could be gained by using an electronic memory store system to operate a variety of replay machines for inserting advertising material and pre-recorded programmes, particularly during the night time operation. However, after trials and careful assessment, it was found that the available random access machines did not give fast enough access time between cartridges to fit into the mode of operation required by Capital Radio. Therefore, only the basic memory and clock-drive system was installed, leaving the options for expansion into automated facilities open for the future.

It has become increasingly popular to invite listeners to telephone studios and ask them to participate in a live programme via the telephone network. However, such programmes require special equipment to cope with the technical difficulties and to this end facilities were provided in conjunction with the Post Office. Fifteen telephone exchange lines were supplied by the Post Office, all responding to the same telephone number and connected to a series of simple key-and-lamp answering units. These are situated in the telephone control room. One unit is connected to all lines and, in conjunction with a normal telephone hand-set, can be used to answer or interview any caller. Each key has three positions. With the key up, a caller on that particular line receives a pre-recorded message from an endless-loop cartridge, explaining that the system is busy. The centre position is a 'ready' position whereby any incoming call is routed on to one of four smaller key-and-lamp units where it can be answered by an operator. With the key down, the producer or controller can speak with the originator of any call before it is selected for onward routing to the studio sound system.

Each of the four smaller key-and-lamp units can be used to answer a call, but if it is required for use in the programme it can be routed on to a final selector switch under the control of a programme technician. In this case, the caller receives a feed of programme sound while he is awaiting his turn. When the call is required for transmission it is then routed through a special amplifier which acts as an electronic hybrid circuit to convert the two-wire telephone system to a four-wire system. This obviates the need for matching the various telephone line impedances as would be necessary were a conventional hybrid transformer to be used. Separation between send and receive signals is better than 35 dB. The incoming signal is then passed through an automatic gain control section of the amplifier and so to an input on a specially designed audio mixer situated in the telephone control room. A 'clean feed' of the studio programme, i.e. all programme material except the incoming calls, is simultaneously connected to the outgoing circuits of the electronic hybrid amplifier.

Studio 2, the smallest studio, is equipped with a small 'self-drive' mixer, two disc reproducers and a cartridge replay machine. The presenter operates his own microphone and equipment, but microphone and disc levels are separately controlled in the master control room. Two other live microphone positions are available in the studio for interviews and news reading, both controlled from the master desk.

Studio 1 control is equipped with a ten-channel mixer, two disc reproducers, one reel-to-reel tape recorder and a cartridge recorder. Because of its position, this control room was arranged so that it could alternatively be used with Studio 3 and microphone tie-lines have been provided. Studio 3 is equipped with an identical mixer to that in master control which is also connected via the solid-state switching matrix mentioned above. This enables the Studio 3 mixer to be brought into immediate operation in the event of a breakdown of the master control mixer. It also permits routine maintenance to take place without disrupting the service. Although Studio 3 was expected to require more than the four microphone channels available, it was decided that this number could be increased at a later date by the addition of a sub-mixer when the requirements became clear. Studio 4 control is supplied with a 16-channel 4-output mixer and it was envisaged that if the need arose to record music programmes, a multi-track recorder could be added at a later stage.

Figure 8 is a schematic of the programme routing of the Capital Radio studios. It shows that the master control room (MCR) forms the nucleus of the system. The master control room is manned throughout the day and night by shift engineers who have the final responsibility for controlling, monitoring and maintaining the quality of the station output. All of the four studios and control rooms in the station can be fed into MCR for the purpose of routing on-air. Normally, however, only one studio or control room is linked to air via MCR, whilst the others are being used for music recordings or other types of programme preparation. In addition to the local studios there are a number of Post Office lines to remote studios. These are used primarily for news and traffic reporting and include facilities at New Scotland Yard, AA Headquarters, Waterloo Station and Heathrow Airport. These remote studios all have self-operating facilities. It will be seen from the schematic that there are also facilities for mobile links into the studios. These include two radio cars used primarily for fast mobile reporting. Programme material from the cars is transmitted on one of the three available UHF frequencies and picked-up at three high-rise receiver sites. Production talk-back is transmitted to the same sites using frequencies in the VHF band. The receiver sites at Millbank, Croydon and Epping Green are linked by Post Office lines via

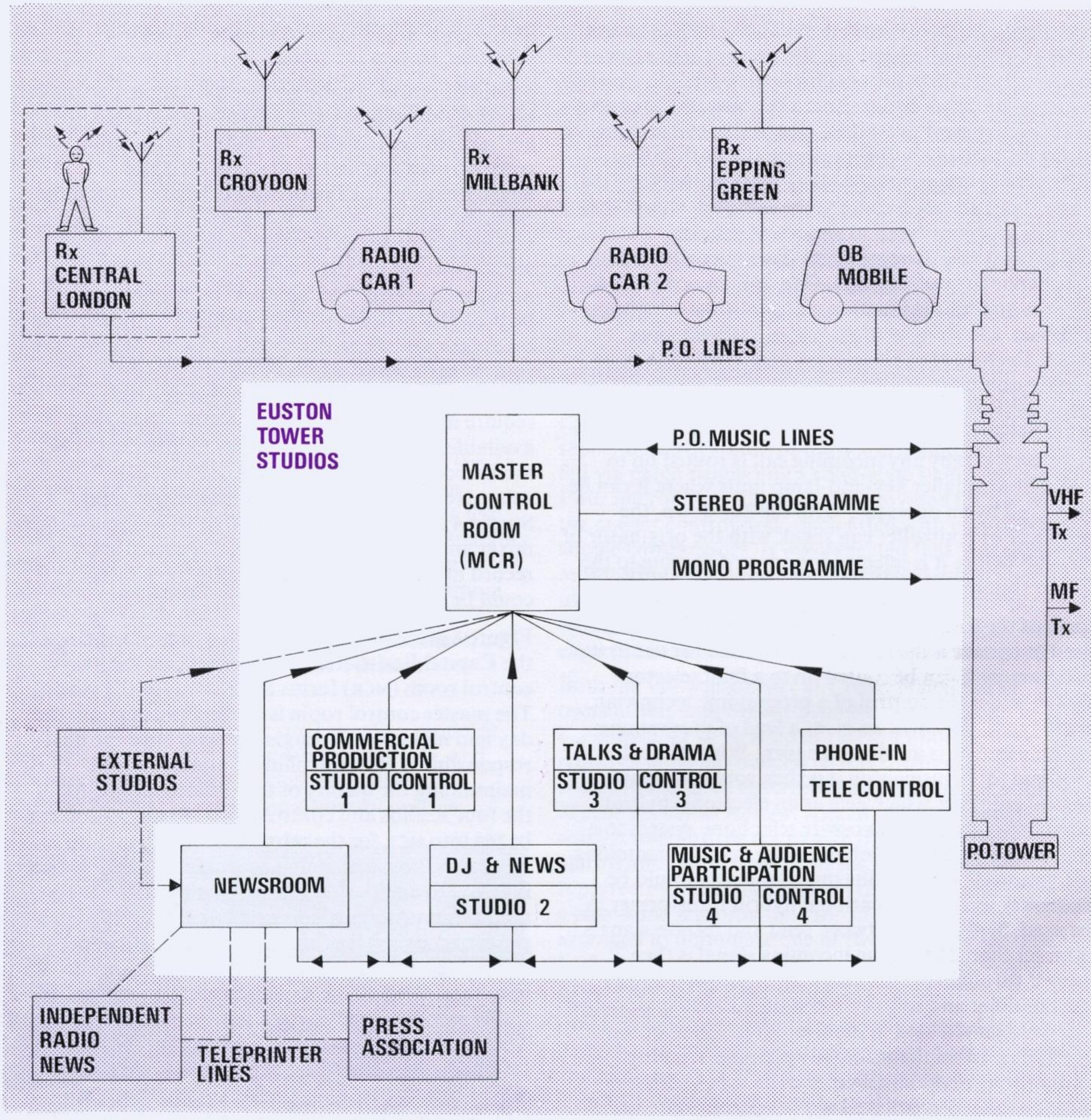


Fig.8. A block diagram showing the basic interconnections used operationally between Capital Radio's sudios and outside facilities.

the Post Office Tower into Capital Radio's master control room.

In addition, for fast mobile news reporting there are available a number of small pocket transmitter/ receivers which work into a single high-rise installation in Central London. A Post Office line, via the Post Office Tower, then provides a link into Capital Radio.

Further, Capital Radio's newsroom, in addition to having a teleprinter feed from the Press Association,

has a teleprinter feed from Independent Radio News (IRN). Both these feeds provide hard copy for the news editors. IRN also provides an audio feed of news reports which is automatically recorded in the newsroom by tone-coded switching.

For larger scale outside broadcasts, whether live into programme or recorded, there is an OB recording mobile unit available. The mobile unit, coachbuilt on a Mercedes chassis, is equipped to act as a small self-contained recording control room or alternatively as a remote master control room taking in feeds from more comprehensive auxiliary mixers which have been de-rigged near the OB site. The unit is thus capable of either feeding direct to Post Office OB lines or recording the event for later transmission.

Staff Recruitment

The Board of Capital Radio Ltd., had made no staff appointments at the time of application for the franchise. Following the granting of the franchise, open advertisements were immediately placed in the major newspapers for the Senior Executive positions of Managing Director, Programme Controller, Chief Engineer, Company Secretary and Sales Director. This resulted in the appointment of most of the senior positions by early June 1973. It was then regarded by the authors as a matter of top priority that technical staff recruitment should begin immediately. Accordingly, advertisements were placed in the technical press in June and July for engineers and technicians to operate and maintain the studios and outside broadcast facilities. The response was very good, and over two hundred and fifty replies were received from people interested in the new industry of commercial radio. This large response enabled very high standards to be set. This fortunate situation resulted in the final selections of technical staff to be made from people with considerable ability, experience and, equally important, a strong desire to contribute to the birth of Independent Local Radio.

As Capital Radio's proposed programme schedule included a significant proportion of outside broadcasts and the studio presentation of music and drama, together with the disc-jockey/news/phone-in format, engineers with specialist experience in recording music were employed as well as broadcast technologists experienced in continuity operations. Generally, technical staff were split into two groups: a maintenance group and an operations group. However, it was a basic point of policy that there would be no strict dividing line between the two. Thus, those engineers employed as technologists could expect to have some operational duties and, depending upon the individual, would be encouraged to become involved in programme operations. Equally, the specialists in operations were expected to have a first-line maintenance capability and would be encouraged to take an active part in engineering development. There were eventually twenty-six engineers employed to cover all the studio and outside broadcast operations and maintenance duties. These were assigned eleven to maintenance and development, eleven to operations and four as trainees. Most of the engineering personnel joined the company during the two months prior to the opening day of the station.

Run-up to First Transmission

The weeks prior to the opening were weeks of continual effort to keep on schedule. With building work still going on in all areas of the studios, the electronics installation team was working extended hours under far from ideal conditions. Installation work had to be carried out with the continual problem of keeping dust and grit from building work out of equipment. Continual vacuum cleaning of studio areas, together with the placing of 'tacky mats' at all the entrances of the studio, helped considerably to reduce the dust problem. Equipment manufacturers and suppliers had to be made fully aware that the delivery dates agreed with them left no room whatsoever for slippage. As there were dozens of different sub-contractors and equipment suppliers involved, a continual day-by-day up-dating of progress was necessary. As could be expected, delays and late deliveries inevitably did occur but these were compensated for by immediately taking whatever corrective action was most appropriate. However, the final stage of installation work, with the building finishing trades working alongside wiremen and engineers, restricted the access to studios for rehearsals during prolonged periods.

Nevertheless, during the two weeks prior to the first transmission, time was found to carry out 'dry runs' of operations. These were gradually extended until they covered a complete twenty-four hour period without a break. Even though these rehearsals had to be carried out without all the facilities being fully installed and working, they proved to be valuable and necessary exercises for both programme and engineering staff. It was during this period that many ideas were tried out and either retained or rejected. Also, operational techniques and procedures were given a short but important test. 'Post mortems' were held following

'dry runs' and, where necessary, revisions to plans and procedures were made. On 14th October 1973, the last dry-run was ended and the studios were cleared for final installation work. The last forty-eight hours were filled non-stop with the work of curing the faults which had come to light during rehearsals and by completing the final installation. Working alongside Capital Radio's engineers were engineers from the IBA who, whilst carrying out tests for Code Practice performance, also gave valuable help and assistance in tackling the final problems.

During the early hours of 16th October, the lines check to the transmitters at the IBA sites at Croydon and Lots Road power station were completed and pronounced satisfactory. At that time Capital Radio took over the feed to line, and the IBA's test transmissions, which had been broadcast for many months, were replaced by 1 kHz tone generated at the studios. At 0455 hrs. this tone was cut and silence remained until, at 0500 hrs. on 16th October 1973 the National Anthem was transmitted from Capital Radio for the first time. The company's Chairman, Mr. Richard Attenborough, then opened the transmissions, welcoming listeners to the new service. From that moment on, a non-stop round-the-clock service has continued.

Engineering Operations

It was one problem to design, build and commission a fully operational stereo broadcasting station inside six months but, once the first transmission was under way, it was an entirely different problem to operate and maintain that station with a continuous, unbroken service. To maintain a round-the-clock broadcast service in both VHF stereo and MF, it was necessary to make adequate arrangements for the operation and maintenance of the four studios and control rooms, the two radio cars, an outside broadcast mobile unit and the central master control room. Together with this, it was necessary that effective administration, security and catering services be available at all times.

Obviously, to ensure the required continuity of output it is necessary to have an effective rolling shift system for engineering staff. This had to be basically simple, adequate to allow for holidays and sickness, cover the whole twenty-four hours of each and every day throughout the year, distribute work loads evenly and also allow shift personnel to take as much of their free time during the normal 'social' hours as possible. After a study of existing shift systems in other industries, one was introduced which went a long way to satisfying the stated requirements. This is a three shift system based on a seven day fortnight. Each staff member works a fortnight on each of the three shifts and has every alternate weekend as a long weekend off. In addition, arrival and departure times for each shift occur, as far as possible, when public transport is available. Generally, this system has proved adequate for most operational requirements. However, to meet deficiencies in covering outside broadcasts and special engineering development projects, a flexi-shift was introduced as an experiment simultaneously with the regular shift system. This proved to be worthwhile when applied to non-routine working requirements.

Conclusion

Following a year's operational experience there is time to reflect on the existing operation and to give some projection into the future.
Experience has shown that within the existing structure improvements in acoustic isolation are necessary. Fundamentally, this is a result of the high-level of sound used currently in popular entertainment causing more isolation problems than were envisaged by the authors. As has already been indicated, work is in progress to improve this. Another area of revision with regard to acoustics is the question of reverberation times. All studios had been designed to comply with the IBA Code of Practice requirements, but in some cases it was later found advantageous to reduce the reverberation times to a value well below the maximum allowable limits in order to more easily meet current requirements for drama and music recording. A further modification to the original plans was found necessary regarding the size and facilities of the self operational disc-jockey studio. Re-location of the studio areas has increased the space and facilities available for this studio.

Another conclusion that the authors have drawn from the first year of operation is that the automated systems currently available were not found to be suitable. This was essentially because of the basic lack of a suitable instant random-access replay machine necessary for the high throughput of Capital Radio's commercial traffic. It is hoped that a later generation of automated replay equipment will enable automation to become a part of commercial radio operations in the United Kingdom. Other lines of development that are under investigation include the utilisation of the Dolby noise reduction technique for FM transmission, and also the use of matrix encoding for the transmission of quadraphonic programmes.

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